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ABSTRACT

The abstracts and critical analyses of research in this document were prepared and compiled to add to the fund of information on the effects of hand-held calculators on achievement and learning. Since many persons find it difficult to secure original copies of all research studies, the expanded abstracts should provide specific information frequently not included in the brief abstracts found in other publications. The critical commentary prepared by each abstractor pinpoints particular strengths and weaknesses noted for each of 36 studies. This document is proferred with the hope that other researchers will profit from analyses of the flaws and strengths in the design of each study. Almost all of the studies comparing achievement of groups using or not using calculators either favor the calculator group or (in about equal number) reflect no significant differences. Areas researched include decimals, problem solving, estimation, division, computational skills, proportion, general mathematics, business mathematics, chemistry, economics, low achievers, and retention. (Author/MP)

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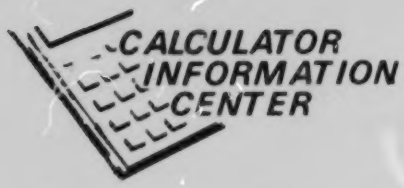

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Investigations with Calculators

Abstracts and Critical Analyses of Research

edited by

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SE 027 581

Table of Contents

Page

Introduction
Marilyn N. Suydam, The Ohio State University 1

Allen, M. B. Effectiveness of Using Hand-held Calculators for Learning Decimal Quantities and the Metric System. Unpublished doctoral dissertation, 1976.

Abstracted by James J. Hirstein, University of Illinois . . . 3

Anderson, L. E. The Effects of Using Restricted and Unrestricted Modes of Presentation with Electronic Calculators on the Achievement and Attitude of Seventh Grade Pupils. Unpublished doctoral dissertation, 1976.

Abstracted by George W. Bright, Northern Illinois University . 6

Ayers, S. W. The Effects of Situational Problem-Solving and Electronic Calculating Instruments in a College Level Introductory Statistics Course. Unpublished doctoral dissertation, 1976.

Abstracted by Marilyn Zweng, University of Iowa 10

Bolesky, E. M. The Influence of Electronic Hand-held Calculators on Cognitive Achievement in Chemistry. Unpublished doctoral dissertation, 1977.

Abstracted by Dennis Roberts, The Pennsylvania State University 14

Boling, M. A. N. Some Cognitive and Affective Aspects of the Use of Hand-held Calculators in High School Consumer Mathematics Classes. Unpublished doctoral dissertation, 1977.

Abstracted by Clyde A. Wiles, Indiana University Northwest . . 17

Borden, V. L. Teaching Decimal Concepts to Sixth Grade Students Using the Hand-held Calculator. Unpublished doctoral dissertation, 1976.

Abstracted by George W. Bright, Northern Illinois University . 22

Eckmier, J. L. An Investigation of the Use of Calculators with Low Achieving 4th Grade students in Mathematics Achievement and Attitude. Unpublished doctoral dissertation, 1978.

Abstracted by Joe Dan Austin, Rice University 26

Page

Fischman, M. L. New York City High School Students' Attitudes and Concept Learnings in Business Arithmetic When Using Electronic Calculators as Contrasted with Hand Calculation. Unpublished doctoral dissertation, 1976.

Abstracted by Dennis Roberts, The Pennsylvania State University 29

Hawthorne, F. S. and Sullivan, J. J. Using Hand-held Calculators in Sixth-Grade Mathematics Lessons. New York State Mathematics Teachers' Journal 25: 29-31; January 1975.

Abstracted by Clyde A. Wiles, Indiana University Northwest . . 32

Hopkins, B. L. The Effect of a Hand-held Calculator Curriculum in Selected Fundamentals of Mathematics Classes. Unpublished doctoral dissertation, 1978.

Abstracted by Edward C. Beardslee, Seattle Pacific University . 35

Hutton, L. A. W. The Effects of the Use of Mini-Calculators on Attitude and Achievement in Mathematics. Unpublished doctoral dissertation, 1976.

Abstracted by James J. Hirstein, University of Illinois . . . 40

Jamski, W. D. The Effect of Hand Calculator Use on the Achievement of Seventh Graders Learning Rational Number-Decimal-Percent Conversion Algorithms. Unpublished doctoral dissertation, 1977.

Abstracted by J. F. Weaver, The University of Wisconsin-Madison . . . 43

Jones, E. W. The Effect of the Hand-held Calculator on Mathematics Achievement, Attitude and Self Concept of Sixth Grade Students. Unpublished doctoral dissertation, 1976.

Abstracted by Clyde A. Wiles, Indiana University Northwest . . 47

Kasnic, M. J. The Effect of Using Hand-held Calculators on Mathematics Problem-Solving Ability Among Sixth Grade Students. Unpublished doctoral dissertation, 1977.

Abstracted by Donald J. Dessart, The University of Tennessee-Knoxville . . . 52

Laursen, K. W. Use of Calculators in High School Mathematics: A Study Comparing Achievement, Attitude and Attendance of General Mathematics Students Who Used Calculators with Students Who Did Not. Unpublished doctoral dissertation, 1978.

Abstracted by Grayson Wheatley, Purdue University 55

Page

Lawson, T. J. A Study of the Calculator's and Altered Calculator's Effect upon Student Perception and Utilization of an Estimation Algorithm. Unpublished doctoral dissertation, 1977.

Abstracted by Grayson Wheatley, Purdue University 58

Lenhard, R. W. Hand-held Calculators in the Mathematics Classroom at Stuart Public School, Stuart, Nebraska. Unpublished doctoral dissertation, 1976.

Abstracted by Marilyn N. Suydam, The Ohio State University . . 61

Lowerre, G. F.; Scandura, A. M.; Scandura, J. M.; and Veneski, J. Using Electronic Calculators with Third and Fourth Graders: A Feasibility Study. School Science and Mathematics 78: 461-464; October 1978.

Abstracted by Robert E. Reys, University of Missouri-Columbia . 64

Miller, D. P. Effectiveness of Using Minicalculators as an Instructional Aid in Developing the Concept and Skill of Long Division at the Fifth Grade Level. Unpublished doctoral dissertation, 1976.

Abstracted by J. F. Weaver, The University of Wisconsin-Madison . . . 67

Muzeroll, P. A. Attitudes and Achievement in Mathematics in Student Choice and Non-Choice Learning Environments. Unpublished doctoral dissertation, 1975.

Abstracted by Donald J. Dessart, The University of Tennessee-Knoxville . . . 72

Nelson, D. W. Effects of Using Hand Calculators on the Attitudes and Computational Skills of Chidren in Grades Four Through Seven. Unpublished doctoral dissertation, 1976.

Abstracted by James M. Moser, The University of Wisconsin-Madison . . . 75

Nichols, W. E. The Use of Electronic Calculators in a Basic Mathematics Course for College Students. Unpublished doctoral dissertation, 1975.

Abstracted by Marilyn Zweng, University of Iowa 80

Prigge, G. and Langemo, J. Effects of Mini-Calculators on the Pre- and Co-Requisite Mathematical Skills of Intermediate School Children. Grand Forks: University of North Dakota, 1978.

Abstracted by Robert E. Reys, University of Missouri-Columbia . 83

Page

Quinn, D. R. The Effect of the Usage of a Programmable Calculator upon Achievement and Attitude of Eighth and Ninth Grade Algebra Students. Unpublished doctoral dissertation, 1975.

Abstracted by James M. Moser, The University of Wisconsin-Madison . . . 86

Rudnick, J. A. and Krulik, S. The Minicalculator: Friend or Foe? Arithmetic Teacher 23: 654-656; December 1976.

Abstracted by James J. Hirstein, University of Illinois . . . 90

Scandura, A. M.; Lowerre, G. F.; Veneski, J.; and Scandura, J. M. Using Electronic Calculators with Elementary School Children. Educational Technology 16: 14-18; August 1976.

Abstracted by Charlotte Wheatley and Grayson Wheatley, Purdue University . . . 92

Scandura, J. M.; Lowerre, G. F.; Scandura, A. M.; and Veneski, J. Using Electronic Calculators with Children Ages 5-7: Four Mini-experiments. School Science and Mathematics 78: 545-552; November 1978.

Abstracted by Robert E. Reys, University of Missouri-Columbia . 96

Schafer, P.; Bell, M. S.; and Crown, W. D. Calculators in Some Fifth-Grade Classrooms: A Preliminary Look. Elementary School Journal 76: 27-31; October 1975.

Abstracted by John E. Tarr and Jack D. Wilkinson, University of Northern Iowa . . . 100

Schnur, J. O. and Lang, J. W. Just Pushing Buttons or Learning? -- A Case for Minicalculators. Arithmetic Teacher 23: 559-562; November 1976.

Abstracted by Dennis Roberts, The Pennsylvania State University . . . 104

Shirey, J. R. The Effects of Computer-Augmented Instruction on Students' Achievement and Attitudes. Unpublished doctoral dissertation, 1976.

Abstracted by Ralph A. Liguori, University of Texas at El Paso . . . 107

Smith, B. L. A Study of the Effectiveness of the Use of the Electronic Calculators in Teaching the Simplex Method to Business and Economics Majors. Unpublished doctoral dissertation, 1977.

Abstracted by Edward C. Beardslee, Seattle Pacific University 110

Page

Sutherlin, W. N. The Pocket Calculator: Its Effect on the Acquisition of Decimal Estimation Skills at Intermediate Grade Levels. Unpublished doctoral dissertation, 1976.

Abstracted by Ralph A. Liguori, University of Texas at El Paso . . . 114

Vaughn, L. R. A Problem of the Effects on Hand-Held Calculators and a Specially Designed Curriculum on Attitude Toward Mathematics, and Retention of Mathematical Skills. Unpublished doctoral dissertation, 1976.

Abstracted by Peggy A. House, University of Minnesota 117

Wajeeh, A. The Effect of a Program of Meaningful and Relevant Mathematics on the Achievement of the Ninth Grade General Mathematics Student. Unpublished doctoral dissertation, 1976.

Abstracted by Peggy A. House, University of Minnesota 121

Yvon, B. R. and Downing, D. A. Attitudes Toward Calculator Usage in Schools: A Survey of Parents and Teachers. School Science and Mathematics 78: 410-416; May-June 1978.

Abstracted by J. F. Weaver, The University of Wisconsin-Madison . . . 125

Zepp, R. A. Reasoning Patterns and Computation on Proportions Problems, and Their Interaction with the Use of Pocket Calculators in Ninth Grade and College. Unpublished doctoral dissertation, 1975.

Abstracted by Joe Dan Austin, Rice University 129

Editorial Note

This document contains abstracts of many, but not all, of the studies which have thus far been published or which are available in the files of the Calculator Information Center. It is anticipated that additional abstracts and critical analyses will be made available in the future.

Introduction to

Investigations with Calculators: Abstracts and Critical Analyses of Research

The abstracts and critical analyses of research[1] in this document were prepared and compiled to add to the fund of information on the effects of hand-held calculators on achievement and learning. Since many persons find it difficult to secure original copies of all research studies, the expanded abstracts should provide specific information frequently not included in the brief abstracts found in, for instance, Dissertation Abstracts International or in the bulletins available from the Calculator Information Center. The critical commentary prepared by each abstractor pinpoints particular strengths and weaknesses noted for each study.

Frequently, the flaws in the research -- or at least in the report of the research -- consume the greater amount of attention. It is comparatively easy to find such flaws. Unfortunately, improving research designs and procedures is a process learned partly through experience, and relatively few of the investigations cited in this compilation were conducted by experienced researchers. Educational research is also hampered by limitations not easily amenable to control nor inexpensive.

But many of the flaws could be amelioriated if not eradicated -- and it is with the hope that other researchers will profit from analyses of these problems that this document is proferred. Obviously, the strengths that are cited can also be of immense help as studies are planned.

While the limitations of the research are cited, it should also be noted that the research on calculators differs from most other bodies of research on particular areas within mathematics education in that the trend of the findings is toward a positive direction. Almost all of the studies comparing achievement of groups using or not using calculators either favor the calculator group or (in about equal number) reflect no significant differences. This contrasts with the "typical" case within mathematics education, in which a bell-shaped, "normal" curve, reflecting a preponderance of findings of no significant differences, prevails.

(Such cases contain studies with flaws similar to those cited in this document.) Thus, the common-sense belief of many mathematics educators that calculators will not adversely affect achievement has some support.

Of even greater concern than the flaws of design or procedure or interpretation, however, is the focus of the majority of the studies on broad, general questions of achievement relative to unspecified or inexplicit use of calculators. Surely, the effect on achievement in general has been of some concern (especially to parents), but there are other, even more important questions to explore. How mathematical learning could change with calculator use would have an obvious impact on mathematics learning, instruction, and curriculum: yet such possible changes have been at the core of relatively few studies. The conference sponsored by the National Institute of Education in January 1979 will attempt to provide guidance to future research efforts, expanding on the report of the conference of June 1976[2].

Thanks are extended to each of the abstractors who contributed to this publication. Their hours spent in reading dissertations and other reports, in abstracting, and in developing critiques will have been rewarded if they serve to help others in planning more effective investigations using calculators.

Marilyn N. Suydam
Director
Calculator Information Center

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1 The format for the abstracts was originally developed by J. F. Weaver for the journal, Investigations in Mathematics Education.

2 Report of the Conference on Needed Research and Development on Hand-held Calculators in School Mathematics. Washington: National Institute of Education and National Science Foundation, 1977. ERIC: ED 139 665.

Allen, Maxine Bogues. EFFECTIVENESS OF USING HAND-HELD CALCULATORS FOR LEARNING DECIMAL QUANTITIES AND THE METRIC SYSTEM. (Virginia Polytechnic Institute and State University, 1976.) Dissertation Abstracts International 37A: 850-851; August 1976. [Order No. 76-17090]

Expanded abstract and analysis prepared especially for the Calculator Information Center by JAMES J. HIRSTEIN, University of Illinois.

1. Purpose

The purpose of the study was to determine whether acquisition and retention of decimal algorithms and metric units are improved by using a hand-held calculator.

2. Rationale

With increased attention to the metric system, the understanding of decimal notation and computation is becoming more critical. Decimal manipulations are easily made on hand-held calculators. The literature reviewed suggests that the use of calculators should enhance the learning of decimal concepts and skills. The extent to which calculators provide an improved mode of instruction needs to be established.

3. Research Design and Procedures

The study was conducted using three sixth-grade classes in each of two schools. In each school, two of the classes were experimental and a calculator was provided for each student, while one control class did not use calculators. Instruction was given for 25 school days. All classes covered the same content: decimals and the metric system. Following the experimental program, all students were given the same unit on fractions so that retention scores would not be affected.

An SRA achievement test was given to all students as a pretest. Two multiple-choice criterion-referenced tests, on decimals and the metric system, were administered three times: before instruction as a pretest, immediately following instruction as a posttest, one month after instruction as a retention test. Use of calculators was not permitted on the criterion tests. The three pretest scores were used as covariates in a multivariate analysis of covariance design using the two posttest scores as criterion

variables. Pretest and posttest scores were used as covariates in a multivariate analysis of covariance using the two retention test scores as criterion variables.

Contamination of the control group was determined by a questionnaire requesting that students report home use of calculators. The analyses were repeated after deleting the control subjects who reported home use of calculators.

4. Findings

Four null hypotheses were tested: that there is no difference in adjusted scores of experimental and control groups on two tests (decimal and metric) given at two times (posttest and retention test).

No significant difference was found between the groups on either posttest. The retention test showed no difference between groups on the decimal test and a significant difference on the metric test in favor of the control group.

When ten control subjects admitting home use of calculators were deleted, no differences on posttests were found. However, this second analysis showed a significant difference in favor of the control group on both retention tests.

5. Interpretations

The differences on retention scores were attributed to an increase in the adjusted mean scores of control subjects from posttest to retention test. The adjusted mean scores of experimental subjects declined over this period. This study did not find that the calculator improved the learning of decimal and metric content as measured by paper-and-pencil tests. Furthermore, retention was lower for students using calculators.

Critical Commentary

Teacher effects were controlled by weekly meetings to discuss progress and procedures, but no report of teacher attitude toward the assigned instructional treatment is given. Furthermore, no effort to monitor classroom adherence to instructional procedures is reported. Because each teacher taught a single class, the results may have been influenced by teacher variables that were not controlled in the experiment.

The instruments used are a serious limitation in this study. The reliabilities are rather low for multiple-choice tests of 20 items: KR_{20} ranged from .47 to .78. The raw score means for decimal and metric pretests for both groups ranged from 33 to 41 percent. The raw score means for posttests and retention tests ranged from 46 to 59 percent, indicating that neither treatment was particularly effective at improving performance on these instruments.

The author notes that paper-and-pencil instruments may have favored the paper-and-pencil treatment and suggests a replication with calculators permitted on the criterion tests. Certainly, if calculators are not permitted, the groups are equalized for testing purposes. However, one advantage of calculator use is that students are able to deal with problems that cannot be handled without a calculator. It should have been easily within reach of this study to address that question, and the absence of this slight extension is unfortunate.

Anderson, Lyle Eugene. THE EFFECTS OF USING RESTRICTED AND UNRESTRICTED MODES OF PRESENTATION WITH ELECTRONIC CALCULATORS ON THE ACHIEVEMENT AND ATTITUDE OF SEVENTH GRADE PUPILS. (University of Denver, 1976.) Dissertation Abstracts International 37A: 6321-6322; April 1977. [Order No. 77-7399]

Expanded abstract and analysis prepared especially for the Calculator Information Center by GEORGE W. BRIGHT, Northern Illinois University.

1. Purpose

The primary purpose was to compare in seventh-grade mathematics classes the unrestricted use, restricted use, and no use of calculators on attitude, achievement, mastery of concepts, computational skill, and problem solving. Effects of sex, socio-economic background, age, and IQ were checked. The secondary purpose was to compare ability of calculator and no-calculator groups to perform single-step and multiple-step computation with whole numbers and decimals with speed and accuracy.

2. Rationale

Reliable data did not exist relative to whether students who have access to calculators will develop dependency on the use of the calculator. The need to conduct research on the effects of use of calculators was cited from several sources.

The literature review of studies involving the use of calculating devices was sketchy. Only 12 studies were cited, and only four of these were dissertations. [Frequently omitted from the summaries of the studies were the number of classes or students, whether the reported unit of analysis was the individual student or the class mean, whether the reported unit of analysis was correct, the probability level of statistical results, and whether the calculating devices were mechanical, electric, or electronic.]

The literature review of attitudes was restricted to a discussion of "a few of the more well-known attitude measuring instruments", which translated almost exclusively into examination of some studies using the Dutton Attitude Scale. [Again, the summaries were quite sketchy.)

3. Research Design and Procedure

The study was conducted in 12 seventh-grade classes (three in each of

the four junior high schools in Sioux Falls, South Dakota) during 1975-76. Two schools served lower socio-economic areas, and two served middle to upper socio-economic areas. In each school the three classes were taught by a single teacher. Teachers were selected by recommendation of their principals, willingness to participate, and at least two years' experience. Assignment of students to classes within a school was random "because the Sioux Falls School System utilized heterogeneous grouping." The total number of students involved in the study was 367.

Pretests were the Cooperative Arithmetic Test (COOP) (Form A), the Stanford Arithmetic Tests (STAV) I, II, and III (Form W, Advanced), the Iowa Tests of Basic Skills (ITBS), the Lorge-Thorndike IQ Test (IQ), and Dutton's Attitude Toward Arithmetic Scale (ATAS). Socio-economic status was determined by whether students received free lunch (poverty level), paid a reduced lunch cost (low income), or paid full lunch cost (all other). Within each school the three classes seemed not to differ on these variables, although there were differences across schools. Posttests were the COOP (Form B), STAV (Form X), ATAS, and Computation Skill Tests (CST) IA, IB, and II (Form A).

In each school, one class (E1) was restricted to using the calculator to verify paper-and-pencil calculations and aiding in the development of specific problem-solving concepts, one class (E2) was allowed unrestricted use of the calculator, and one class (C) was allowed no use of the calculator. School policy was that no homework be assigned to students. Students in E1 and E2 classes were told that calculators would not be allowed during tests. These classes, however, were allowed to use calculators for CST IA, IB, and II. For each teacher the selection of the three participating classes was random from among all of that teacher's classes, and the assignment of treatments to classes was random. In E1 and E2 classes, one Rockwell '76 calculator (four operations, storage key, recall key, and percent key) was assigned to each two students. Pretesting was done during the eleventh week, the treatment lasted eighteen weeks, and posttesting was done during the next week. Classroom instruction was conducted by the classroom teachers.

Twenty-four predictor variables (pretests, sex, school, socio-economic level, age on September 1, and treatment group) and eight criterion variables were used. Each criterion variable was analyzed an ANCOVA, with the

covariates being significantly correlated attribute predictor variables and the criterion variable's corresponding pretest. The Newman-Keuls method of multiple comparisons was applied whenever a significant F value was observed for an ANCOVA.

4. Findings

Eight null hypotheses were tested. In each case the reported degrees of freedom for the F-statistic was based on the total number (325) of students with complete data.

a. There was a significant effect on attitude (ATAS), with E2 > C ($p < .01$), E1 > C ($p < .01$), and E2 > E1 ($p < .05$).
b. There was no effect on overall achievement (COOP).
c. There was no effect on mastery of concepts (STAV-I).
d. There was no effect on computation skill (STAV-II) when calculators were not allowed.
e. There was a significant effect on problem solving (STAV-III) when calculators were not allowed, with only E2 > C ($p < .05$).
f. There was a significant effect on a timed test of single-step computation (CST-IA) when E1 and E2 classes were allowed use of a calculator (one per student) but C classes were not, with E1 > C ($p < .01$) and E2 > C ($p < .01$).
g. There was a significant effect on a timed test of multiple-step computation (CST-IB) when E1 and E2 classes were allowed use of a calculator (one per student), but C classes were not, with E1 > C ($p < .01$) and E2 > C ($p < .01$).
h. There was a significant effect on an untimed computation test (CST-II) when E1 and E2 classes were allowed use of a calculator (one per student) but C classes were not and when the student score was number of correct problems per minute of elapsed time (recorded for each student), with E1 > C ($p < .01$) and E2 > C ($p < .01$).

5. Interpretations

Calculators can be placed in seventh-grade mathematics classes without special curriculum changes or special training of teachers. No adverse effect is caused on overall achievement, mastery of concepts, or computation skill. Positive effects occur for problem solving and attitude. Use of

calculators allows students to solve computation problems at a faster rate.

Critical Commentary

The strength of this study is its realistic approach to the use of calculators. The three treatments reflect three positions frequently espoused by teachers.

The major weakness of the study is its assumption that students were assigned randomly to treatments. The experimenter apparently had no control over the assignment of students to classes, and one can imagine lots of circumstances (e.g., band or athletics) that might prevent true random assignment. Even with random assignment of students to classes ten weeks before the experiment began, however, each class had time to develop its own special character and system of interpersonal interaction. Intact classes were assigned to treatments, so the unit of analysis should have been the class mean. The true N, therefore, was 12, not 325. This has serious implications for the analyses. In particular, the correlational analysis preceding each ANCOVA would probably not be useful. It is unfortunate that the dissertation does not contain the class means on the posttest scores (class means of pretest socres are reported) so that reanalysis could be performed.

Three minor weaknesses should be noted. First, the C classes probably knew that the E1 and E2 classes were using calculators. This could at least partially explain the significant effect on attitudes. Second, the instructional treatments were poorly defined. Each teacher was supposed to teach each of the classes the same, except of course for the use of calculators, but there were apparently no checks of whether the instruction was actually the same across classes within each school. Third, the interpretations and recommendations for future (less than two pages among 98 pages of text and tables) are very superficial. The author presents his data but he doesn't significantly further the cause of providing an adequate context within which to understand the effects of calculator use in school mathematics.

Ayers, Sharon Whitton. THE EFFECTS OF SITUATIONAL PROBLEM-SOLVING AND ELECTRONIC CALCULATING INSTRUMENTS IN A COLLEGE LEVEL INTRODUCTORY STATISTICS COURSE. (Georgia State University, 1976.) Dissertation Abstracts International 37A: 6322-6323; April 1977. [Order No. 77-9305]

Expanded abstract and analysis prepared especially for the Calculator Information Center by MARILYN ZWENG, University of Iowa.

1. Purpose

The subjects in this study were non-science and non-mathematics majors enrolled in a college-level introductory statistics course. The two major purposes were to determine the effect on student achievement and attitude of (a) the use of electronic calculators and (b) instruction in situational problem-solving heuristics. The author defines "situational problems" as problems which involve realistic applications of mathematics. Typically, situational problems are not well-defined. The student must decide what specific questions are to be answered, what data must be collected, and what procedures must be used for analysis of the data. Two of the problems from the experimental course which typify the author's interpretation of siutational problems are, "Do you have extra-sensory perception?" and "What is the best way to take a test?"

2. Rationale

Several major reports and, in particular, the NACOME report, have recommended more extensive use of calculators and more exposure to "real" problems in mathematics instruction. Electronic calculators have been used extensively in the teaching of statistics for many years, but, according to the author, there has been no evaluation of the effect of calculator usage on attitude and achievement. On the other hand, instruction in situational problem solving is not a common practice. The research review found only one citation in the literature that described a program in which students were exposed to real-life situations in a statistics course. In this instance, the achievement and attitude of the students had not been evaluated and, furthermore, the applications were too "well-defined" to meet the criteria of being situational problems.

3. Research Design and Procedures

Four classes of 25 students took part in the study throughout the 1975 Winter Quarter. All students were non-science and non-mathematics majors at Georgia State University. Two time periods, both mid-day, were involved. The 50 students within a time period were randomly assigned to the two classes meeting at that time. There were two teachers and four treatments which were combinations of instructional mode and computational method. The four treatments formed a two-by-two factorial design. The assignment of times, teachers, and treatments is shown in the table:

Group	Time	Teacher	Treatment
1	11:40-12:30 daily	A	Situational Problem Solving (S) Electronic Calculators (E)
2	11:40-12:30 daily	B	No Situational Problem Solving (NS) No Electronic Calculators (NE)
3	12:40-2:00 MWF	B	Situational Problem Solving (S) No Electronic Calculators (NE)
4	12:40-2:00 MWF	A	No Situational Problem Solving (NS) Electronic Calculators (E)

A 75-item investigator-designed achievement test with a reliability coefficient of .75 was administered at the end of the quarter. No pre-tests were given. This was a posttest-only design. Students in the calculator treatment were allowed to use calculators during the examination; students in the non-calculator group were not provided calculators during the exam. Students' attitudes towards mathematics were measured by the McCallon-Brown semantic differential scale. An investigator-developed View of Statistics Inventory was also administered to the subjects. The VSI is an adaptation of Rettig's View of Mathematics Inventory.

A two-way ANOVA was used to determine the effects of instructional mode and computational method on achievement. The effects of treatment on attitude towards mathematics and view of statistics were analyzed by several applications of the Mann-Whitney U test. In order to identify associations among the three measures (achievement, attitude, and VSI), a Kendall Tau rank correlation coefficient was computed for each pair of measures.

4. Findings

A. Between calculator and non-calculator groups

(1) Achievement: The calculator group scored significantly higher on the achievement test than the non-calculator group.

(2) Attitude towards mathematics: No difference

(3) View of Statistics: No difference

B. Between situational problem-solving and non-situational problem-solving groups

(1) Achievement: No difference

(2) Attitude towards mathematics: No difference overall; however, for the subset of students who did not use calculators, the situational problem-solving group had a more positive attitude. In classes where the calculators were used, there was no difference between the attitudes of the two groups.

(3) View of Statistics: The situational problem-solving group demonstrated much higher esteem for statistics than the control group.

C. Relationships between measures: There was a positive correlation between all pairs of measures; achievement and attitude, achievement and View of Statistics, and attitude and View of Statistics.

5. Interpretations

The researcher concludes that "these results provide support for the insructional mode termed 'situational problem-solving'" and "the results . . . strongly support the use of electronic calculating instruments in a college-level elementary statistics course." The first conclusion is based on the positive effect of situational problem-solving on attitude towards mathematics and View of Statistics and the fact that situational problem solving did not interfere with the acquisition of standard course content. The investigator notes that the superior achievement of the calculator group might be questioned because this group had access to calculators during the Statistics Content Achievement test and the non-calculator group did not. She speculates, however, that the difference between groups would still have existed if the testing situation had been the same for both groups, since computational errors accounted for only a small portion of the achievement score.

Dr. Ayers also suggests that the results of her study have implications for the use of calculators and situational problem solving in the secondary school.

Critical Commentary

This was a superbly designed and executed study. Student and teacher variables were well controlled by random assignment to treatments and by the comparable time periods in which the classes met. The number of subjects, 100, was adequate and the utilization of a two-by-two factorial design in essence doubled the sample size since there were 50 students under each of the four treatments, S, NS, E, and NE. The statistics to analyze attitudinal measures is commendable. All too often parametric methods are inappropriately used on ordinal measures.

It appears to this writer that despite the question raised about the non-equivalent testing conditions, the results are conclusive. Teachers of elementary statistics should take careful note of this study. The usefulness of the study is further enhanced by the very complete appendices. All instruments used in the study are provided in their entirety. They not only have good test-retest reliability but also appear to have excellent content validity. Additionally, an outline of the course and the complete set of situational problems assigned during the quarter are provided. Teachers who are considering developing a similar course will find the appendices very helpful.

Bolesky, Edward Michael. THE INFLUENCE OF ELECTRONIC HAND-HELD CALCULATORS ON COGNITIVE ACHIEVEMENT IN CHEMISTRY. (Boston College, 1977.) Dissertation Abstracts International 38A: 1319-1320; September 1977. [Order No. 77-11,622]

Expanded abstract and analysis prepared especially for the Calculator Information Center by DENNIS ROBERTS, The Pennsylvania State University.

1. Purpose

The intent of this investigation was to examine the effect of the use of hand-held electronic calculators on chemistry achievement of secondary school students enrolled in a CHEM Study chemistry course.

2. Rationale

The rationale offered for conducting this study involves five factors. First, available opinions are mixed concerning the utility and desire for allowing students to use calculators for classroom learning activities (especially pre-college). Second, the available research literature indicates no negative effects due to classroom use of calculators and, in many instances, there are demonstrable positive effects. Third, the majority of the calculator research has been done at the elementary school level in basic mathematics instructional settings. Fourth, high school chemistry (CHEM Study, in particular) demands and incorporates many mathematical computational and conceptual skills of the chemistry students. Hence, and fifth, it would be worthwhile to see if calculator use might have significant impacts on student achievement in a CHEM Study setting.

3. Research Design and Procedures

The participants in the study were 80 students enrolled in four sections of a CHEM Study course in a rural school in Massachusetts. Students were randomly assigned to one of the four sections. Two sections were designated as experimental classes and students in both were given a small hand-held calculator (Texas Instruments SR-11), which was used in class throughout the semester for reviewing homework assignments, for assisting on computations, for performing necessary calculations during laboratory exercises, and for performing necessary calculations on in-class tests and quizzes. The other two sections were designated as controls and did not have class-

room access to calculators during the semester.

All students were posttested with Form E of the Anderson-Fisk Chemistry Test (55 items covering knowledge, comprehension, and application levels of Bloom's Taxonomy) and a teacher-constructed test (50 items). Reliabilities were reported as .90 for the Anderson-Fisk Chemistry Test (from the manual) and .84 for the teacher-made test (from the current study). During posttesting, one of the experimental classes and one of the control classes were allowed to use calculators on the tests, whereas the other experimental class and the other control class worked problems by paper-and-pencil methods. Hence, the design was such that half of the students used calculators during instruction and half of the students didn't and, subsequently, half of each of those groups used calculators on the criterion tests and half didn't. Hypotheses concerning achievement due to calculator use (or non-use) during instruction, calculator use (or non-use) during posttesting, or the interaction between the two factors were all stated in the null form. No directional hypotheses were put forward based on the rationale developed and literature cited.

4. Findings

Two two-way analyses of variance were performed, one for the Anderson-Fisk test data and one for the teacher-constructed test data. For each analysis, the independent variables were mode of instruction (use or non-use of calculators) and mode of testing (use or non-use of calculators). Alpha was set at .05 for each significance test. No significant main effects nor interaction effects were found for either the Anderson-Fisk Chemistry Test data (analyzed by separate knowledge, comprehension, and application levels, plus total score) or the teacher-constructed test.

5. Interpretations

Three possible reasons were offered for the failure to find differences between experimental and control groups. First, while students were shown how to operate the calculators, they were not given instruction on ways to integrate calculator use with the chemistry problem-solving process. Second, the added time it took the control students to work the chemistry problems might have offset possible benefits from calculator use in the experimental classes. And third, outside use of calculators by students

in the control groups might have reduced the observable effect of calculator benefits as evidenced in the experimental groups.

Critical Commentary

The major problems with the present study are ones the author himself commented upon -- those being possible contamination of the treatment (calculator use) with the control group, and the lack of specific instruction whereby calculator use is integrated into the chemistry problem process. While control of the first problem is difficult, the failure actively to incorporate calculators into the instructional strategy of the experimental group is a serious design flaw. Any study that is interested in examining calculator benefits on higher-level cognitive mathematical (or related) skills must carefully plan the instructional sequence in the experimental groups in such a way as to utilize the capabilities of a calculator to facilitate problem solving.

Boling, Mary Ann Neaves. SOME COGNITIVE AND AFFECTIVE ASPECTS OF THE USE OF HAND-HELD CALCULATORS IN HIGH SCHOOL CONSUMER MATHEMATICS CLASSES. (The Louisiana State University and Agricultural and Mechanical College, 1977.) Dissertation Abstracts International 38A: 2623-2624; November 1977. [Order No. 77-25,370]

Expanded abstract and analysis prepared especially for the Calculator Information Center by CLYDE A. WILES, Indiana University Northwest.

1. Purpose

The purpose of this study was to assess some cognitive and affective effects of using a hand-held electronic calculator for all computations in twelfth-grade consumer mathematics classes. The experimental variable was simply the use or non-use of the calculator in solving all problems. Thus, the study attempted to answer two questions:

a. Does the use of the hand-held calculator in high school consumer mathematics classes result in significant gains in student achievement in mathematical verbal problem solving?

b. Does the use of the hand-held calculator in high school consumer mathematics classes result in improvement of student attitudes toward mathematics?

2. Rationale

The easy availability of mini-calculators and widespread professional speculation about the probable impact of their use provide the primary motive for this study. Of particular importance is the expectation that if calculators are used to remove the tedium and complexity of calculation from the study of problem solving, then problem solving can be more efficiently and enjoyably studied.

Studies reported since 1956 were reviewed with particular reference to

a. the relationship between computational skill and problem solving in mathematics, and

b. the cognitive and affective effects of using calculators in the classroom.

The author concluded that Riedesel's position (Arithmetic Teacher, January 1969, p. 54) is not now supported by the bulk of research. Riedesel wrote "that while the improvement of computation is important to problem solving

ability, the improvement of computation alone has little, if any, measurable effect upon reasoning and problem solving." The following rationale was advanced for the study:

> If the improvement of computation does significantly affect problem solving ability, then the use of calculators to perform the necessary computations should promote more efficient solving of verbal mathematical problems. (p. 9)

The review of studies of the cognitive and affective effects attributable to the use of calculators led to the conclusion that most studies were inconclusive and that further research was needed. It may be noted that of the four studies reviewed that showed significant effects, two involved secondary school students, and both involved instructional materials specifically designed for use with calculators.

3. Research Design and Procedures

During the 1975-76 school year, students from seven twelfth-grade consumer mathematics classes in Jackson, Mississippi were randomly assigned as intact classes to one of two instructional arrangements. Five of the seven classes were federally funded Emergency School Aid Act classes for underachievers. The assignment controlled for type of class and instructor. There were 51 students in the experimental group and 43 in the control group. The average mathematics grade and overall high school academic average for the resulting two groups was D. IQ scores from elementary school records ranged from 60 to 130 with means of about 95.

Instruction for all classes began with a rational numbers computation unit without reference to calculators. This was followed by a 19-week experimental period. During the 19 weeks the experimental classes were provided with four-function, battery-operated, hand-held calculators. Following one and one-half class periods for orientation, instruction in calculator use was provided individually as needed. The calculators were to be used in solving all problems in units related to banking, credit, taxes, paychecks, consumer shopping,and budgeting. The control classes worked through the same materials but were required to use usual paper-and-pencil computational procedures.

The dependent variables were scores on a 15-item verbal problem-

solving subtest of the 1970 California Achievement Test for secondary students with modified testing procedures, scores on a 20-item mathematics attitude scale, and responses to a three-item verbal opinion poll of the experimental group.

The times of administration of the achievement test was determined by the regular testing program of the school system. These times were six weeks prior to the beginning of the experimental periods, and again at the end of the 19 weeks. The attitude (Agree, Undecided, Disagree) was administered at the beginning and end of the 19 weeks, and the opinion poll was given near the end of the school year several weeks after the calculators had been taken from the classes.

Standardized testing procedures for the achievement test were modified in several ways. First, each subject was required to complete two answer sheets, one for the testing program and one for the study. Following the 12-minute time limit specified by the standardized test, students were allowed to continue working on the second answer sheet for as long as they wished. And finally, the author reports that the experimental group was allowed the use of the calculator during the post-test while the control group was not. While one might suppose that both groups were denied the use of the calculator during the first 12 minutes of the test, the matter is unclear.

4. Findings

Both groups showed improvement in their posttest achievement means of a little over two items on a 15-item test. Extensive analysis, however, failed to discover any differences between the groups in either total score or gain score. No improvements in general mathematics attitude were observed for either group, and no differences were found between the groups. The opinion poll, however, that focused upon the student's feelings about the use of the calculators, showed a vast preponderance of positive student responses. With very few exceptions, students said they felt more confident in their work and enjoyed class a great deal more when calculators were used.

5. Interpretations

Computation as affected by the use of calculators did not appear to be a major factor in the verbal problem-solving ability of the students in this study. And while the students expressed positive feelings toward the use of calculators, their attitudes toward mathematics in general were not improved.

It was recommended that a population more normally distributed with respect to mathematics ability be employed in further research of the basic relationship between computational skill and verbal problem solving, and that tests specifically designed for consumer mathematics courses be used. It was also recommended that proper calculator operation be taught in consumer mathematics classes and that curriculum materials developed for use with calculators be employed.

Critical Commentary

This seemed to be basically action research based on the existence of a new tool and available students in a special program with special instructional needs. The attempt to fit the study into the theoretical constructs of problem solving is to be commended, although it seems to be forced and perhaps constructed after the fact. Had the study reported significant differences, it would be necessary to comment upon a number of design weaknesses. As it is, the author's summary and conclusions are quite appropriate.

In terms of the basic relationship between computational skill and problem solving, the data support the position of Riedesel that improving calculation ability alone has little measurable effect on problem-solving scores. But, here too, some reservations must be made. While we have ample reason to believe this group of students was very poor at computation, no data were reported to assess just how poor they may have been. This is unfortunate as some data were surely available from the standardized testing program of the school. Furthermore, we have no data to establish that the calculators affected the students' ability to compute at all. The author in fact recommends that proper calculator operation be taught. And finally, we do not know to what degree any of the students possessed the ability to compute answers to the problems of the achievement test with or without calculators.

The study does provide some information, however. First, it is clear that these students welcomed the calculators and valued them long after the simple novelty of the machines had worn off. The investigator, as a professional teacher, is apparently quite convinced of the motivational value and classroom usefulness of the calculators for these students, and this was, of course, the purpose of the study from an action research point of view.

Finally, while action research is often a bit "loose" in terms of rationale and hence theoretical implications, the practical implications were nearly lost as well simply because inadequate and insufficient measures of student performance were made.

Borden, Virginia Lee. TEACHING DECIMAL CONCEPTS TO SIXTH GRADE STUDENTS USING THE HAND-HELD CALCULATOR. (University of Northern Colorado, 1976.) Dissertation Abstracts International 37A: 4192; January 1977. [Order No. 76-29,734]

Expanded abstract and analysis prepared especially for the Calculator Information Center by GEORGE W. [illegible]IGHT, Northern Illinois University.

1. Purpose

The primary purpose was to investigate in sixth-grade mathematics classes the effects of the use of hand-held calculators on attitude and on achievement and retention of concepts and skills in decimal fractions. The secondary purpose was to compare the effectiveness of teaching of decimal fractions before common fractions with the effectiveness of teaching common fractions first.

2. Rationale

There are controversies regarding both the use of calculators and the sequencing of instruction on common and decimal fractions. The study was designed to investigate some aspects of these controversies in order to obtain needed research data.

A brief theoretical orientation (with noticeable overgeneralizations of Piaget's theories) was provided. The relationship of the study to the theory was not clearly delineated.

A sketchy review of research literature on the use of calculators was given. (Several studies, cited from secondary sources, were not referenced directly and apparently were not read. Also, summaries of studies did not include complete information.) Numerous citations were made of articles which gave only opinions about the use of calculators.

Only two research studies were cited as background for the research on sequencing of decimal and common fractions. One of these citations was from a secondary source. Again, numerous citations of opinion were given.

3. Research Design and Procedures

All four sixth-grade classes (N = 85) at Windsor Middle School (Windsor, Colorado) and both sixth-grade classes (N = 41) at University Middle School

(Greeley, Colorado) participated. Noticeable differences in family backgrounds between student populations in the two schools were acknowledged.

The Windsor School students were taught a unit on an introduction to and the four operations with decimal fractions. The unit was both written and taught by the experimenter. The lessons were teacher-directed but involved worksheets to accompany the teachers' activities. Students in two randomly selected classes (one from the two morning classes and one from the two afternoon classes) used calculators "to check problems, to solve problems, to discover patterns, to aid in decimal fraction oriented activities, to solve puzzles, [and] to play games." The other two classes did not use calculators. The students "had not completed" their study of common fractions before the unit on decimal fractions began. (Their background in common fractions was not described. At another point in the dissertation it is stated that "the Windsor students had not studied common fractions." This inconsistency in reported background was not resolved.) The unit lasted four weeks, and all work was done in class.

The University School students completed a unit (of unreported length) on decimal fractions from their textbook. They had studied common fractions prior to decimal fractions.

Pre- and posttests on decimal fractions were written by the experimenter. Each of the parallel tests contained 23 items: three translations from words to symbols, six comparisons, five addition/subtraction, five multiplication/division, and four word problems. Reliabilities were not reported, although the tests are reproduced in an appendix. The pretest was also used as a retention test (in Windsor School only) three weeks after the posttest. A 20-item survey, adapted from NLSMA, was used in both schools as a pretest and posttest and in Windsor School only as a retention test. (The scoring of the items was not uniform, because of a varying number of choices per item.) The survey is reproduced as an appendix. The order of administration of the two instruments at each testing period was not reported.

The calculator used was Sharp EL-8016R (four operations, square root, and percent keys). It has floating decimal point and algebraic calculation system. Each student in the calculator classes had her or his own calculator. Students in the two Windsor School non-calculator classes were told they would use the calculators after the unit on decimal fractions.

The analysis of each hypothesis was by a t-test on gain scores. The reported unit of analysis in all cases was the individual student.

4. Findings

Fourteen hypotheses were tested. At Windsor School significant gains were noted for pre-post comparisons of achievement for the calculator students ($p < .05$) and the non-calculator students ($p < .05$). A significant decrease in attitude was noted for the non-calculator students ($p < .05$), but no significant difference was noted for the calculator students. In comparisons of subgroups (gain scores in all cases), there were no significant differences on achievement or attitude between calculator and non-calculator classes for either pre-post or post-retention comparisons between morning and afternoon classes for pre-post comparisons, or between boys or girls for pre-post comparisons.

All four Windsor School classes as a group were compared to the two University School classes as a group using pre-post gain scores on achievement and attitude. Neither comparison produced significant statistics.

Pre-post gain scores for achievement and attitude were reanalyzed separately for each of the four Windsor School classes. Achievement gains were significant ($p < .05$) for each class. Only one class, a non-calculator class, showed a significant attitude change ($p < .05$), and that change was negative.

5. Interpretations

Students learned significantly in both calculator and non-calculator modes. Decimal fractions can be successfully taught before common fractions. There were no differential effects between modes.

Based on observations it was concluded that (a) students who used calculators had more positive attitudes than those that did not, (b) morning classes had higher achievement gains and more positive attitudes than afternoon classes, (c) boys made greater achievement gains than girls, (d) girls had more positive attitudes than boys, (e) sixth-graders need very close supervision in the use of calculators, and (f) students need more work with estimation in order to use calculators effectively.

Critical Commentary

The study contains serious methodological flaws. First, the unit of analysis was incorrectly designated as the individual student. For those comparisons of a group with itself (4 of the 14 hypotheses), the individual student is correctly the unit of analysis. For comparison of one group against another (10 of the 14 hypotheses), the unit of analysis must be the class mean (N = 4 or N = 6), since the treatments were assigned to classes rather than students. (For the ten hypotheses affected by this consideration, however, no significant differences were reported.)

Second, the comparisons between the two schools are not legitimate because, as the experimenter admits, the populations were not comparable and treatments were not randomly assigned across schools.

Third, the use of gain scores and multiple t-tests is suspect. A better experimental design should have been sought.

There are also some concerns about the conceptualization of the problem. The two areas of investigation, calculators and sequencing of common and decimal fractions, are not naturally related. There is not sufficient rationale provided for the inclusion of both areas in one study. Too, the reader loses confidence early on when the overgeneralizations of Piaget's work are presented.

Finally, the conclusions are too strong and are too dependent on trends in the data and "observations". The experimenter doesn't seem to want to believe the nonsignificance of the computed statistics.

Because of flaws in design, the study lacks credibility. The severe limitations that must be placed on the reported findings and interpretations render it virtually useless in furthering an understanding of the effects of calculators.

Eckmier, Janice Logan. AN INVESTIGATION OF THE USE OF CALCULATORS WITH LOW ACHIEVING 4TH GRADE STUDENTS IN MATHEMATICS ACHIEVEMENT AND ATTITUDE. (University of Southern California, 1978.) Dissertation Abstracts International 38A: 7109; June 1978.

Expanded abstract and analysis prepared especially for the Calculator Information Center by JOE DAN AUSTIN, Rice University.

1. Purpose

"The purpose of this study was to investigate the effects of calculators on low achieving 4th grade students' achievement in mathematics computation. An additional purpose was to determine if student attitudes toward mathematics were changed by the use of calculators in the classroom." (p. 14)

2. Rationale

The investigator argues that it is logical to expect that calculators would be particularly useful in the teaching of slow learners. The reason for this is that slow learners generally need immediate feedback and generally have problems with computation. The calculator has the potential of assisting in both of these areas. The investigator also argues that the elementary grades seem particularly suited to using the calculator with slow learners. This is because of both the mathematics curriculum and the formation of student attitudes toward mathematics during these grades. The investigator believes that "age nine, or 4th grade, may prove to be a crucial age where calculators may have the greatest affect on the achievement and attitude of slow learners." (p. 43)

3. Research Design and Procedures

Students in six intact fourth-grade classes at four schools were involved in this year-long study. Classes were selected so two classes were chosen from each of three levels of socio-economic status (SES) -- low, middle, and high -- based on average family income. For each SES one class (experimental) used calculators at least 50 percent of the weekly class time for checking problems and doing other calculator assignments. The other class (control) did not use calculators. All six classes

were taught by experienced teachers using the same textbook. Initially 120 students were involved in the study. However, during the year-long study, transfers and extended absences during testing reduced this to 108 students. Further, the class sizes were unequal and ". . . using a table of random numbers, each classroom had to be reduced to an equal sample size . . .". (p. 64) All analyses were done on data from the remaining 90 students.

Five pretest measures were administered. Four measures were Metropolitan Achievement Tests (Reading Achievement, Mathematics Computation, Mathematics Concepts, and Mathematics Problem Solving). The other was a Mathematics Attitude measure. Except for the Reading Achievement Test, the same tests were given as posttests. No calculators were used on any of the tests.

A two-way analysis of variance was used in all analyses. The two factors were SES (three levels) and Group or Treatment (two levels). The initial comparability of classes was tested using the Reading Achievement data. The evaluation of treatment effects was done on the gain scores (posttest minus pretest) for each of the other four variables.

4. Findings

All statistical tests were made at the alpha level of .05. No initial differences between classes on SES or Grouping were found for Reading Achievement scores. The analyses of variance on the gain scores did not indicate significant treatment effects for the other measures -- Mathematics Computation, Concepts, Problem Solving, and Attitude. The effect of SES was significant in each analysis of gain scores except for Mathematics Concepts. (No additional tests were made on these differences.) None of the interactions was significant.

5. Interpretations

The investigator drew the following conclusions: (p. 102)

a. The use of hand-held calculators in the classroom does not improve students' ability to compute, understand concepts, or solve problems.
b. Improvement of fourth graders' attitudes toward mathematics is not positively affected by the classroom use of calculators.
c. The use of calculators does not differentially affect a specific

level of socio-economic status in the areas of academic achievement or attitude change.

The investigator recommends that additional research should be done to "attempt to discover what types of calculator activities are most appropriate for children at various ages." (p. 103)

Critical Commentary

Although this study lasted the entire school year, the investigator does recognize many of the limitations of a study using intact classes. The variety of achievement measures seems quite appropriate in preliminary studies on the effects of using calculators in the classroom.

This reviewer had a question concerning the random deletion of subjects to achieve equal class sizes. Why was this necessary? Another question concerns the rationale for using SES as a classification variable. Although both the rationale for the study and the literature review (with desk and hand-held calculator research considered) were very complete, neither included any discussion of SES.

One final question relates to the role of the investigator. Specifically, what if special training or materials were provided the six teachers before and/or during the study? If the teachers received no special training or materials, the results may suggest that simply using calculators without altering the material or teacher training does not necessarily produce the anticipated improvement in performance and attitude of slow learners. If the teachers did receive special training and materials, the investigator's suggestion for further research on specific calculator activities would seem particularly appropriate.

Fischman, Myrna Leah. NEW YORK CITY HIGH SCHOOL STUDENTS' ATTITUDES AND CONCEPT LEARNINGS IN BUSINESS ARITHMETIC WHEN USING ELECTRONIC CALCULATORS AS CONTRASTED WITH HAND CALCULATION. (New York University, 1976.) Dissertation Abstracts International 37A: 774-775; August 1976. [Order No. 76-19,025]

Expanded abstract and analysis prepared especially for the Calculator Information Center by DENNIS ROBERTS, The Pennsylvania State University.

1. Purpose

The intent was to determine if the use of electronic calculators would improve the mathematics attitudes and business arithmetic achievement of New York City high school students.

2. Rationale

The basic rationale offered was that students, especially lower ability ones, are frequently frustrated by the amount of failure they encounter when working quantitative problems directly involving paper-and-pencil manipulations with basic arithmetical operations. Such frustration leads to decreased motivation (attitudes) to want to work such problems and hence, delays or retards the learning of new material involving the basic operations. Calculators, especially the highly efficient and accurate electronic ones, should substantially reduce such computational frustration and therefore improve attitudes towards mathematics which, in turn, would improve business arithmetic achievement. The literature review included no studies where electronic calculators were used, and was split fairly evenly between references to studies involving mechanical devices and articles offering opinions about the use of such aids in the learning of mathematics. Hypotheses offered were: There is a difference in attitudes towards mathematics for those using calculators versus those who don't, and there is a difference in business arithmetic skills and knowledge of concepts for those using calculators during instruction (when used in the posttests) versus those who don't, but no difference in business arithmetic skills and knowledge of concepts for those using calculators during instruction versus those who don't when neither group can use calculators on the posttests. Although the hypotheses were not stated in a directional form, the

implication was that instruction utilizing calculators would be beneficial to attitudes, but only beneficial to arithmetical skills when students could continue to use the machines on the criterion measures.

3. Research Design and Procedures

The procedures and results from both a pilot study and a main investigation were presented. In the pilot study conducted during the beginning semester of 1971, four business arithmetic classes were used: two for the experimental condition (used calculators during the semester) and two for the control condition (no classroom access to calculators). Students were pretested and posttested with the New York Arithmetic Computation Test. During posttesting, students in the experimental classes completed one posttest using the calculator (Singer 1115, four functions plus constant) and an alternate form by hand. Control students worked only by hand. Attrition from pretest to posttest was nearly 50 percent for both the experimental (57 → 30) and control (65 → 37) classes.

The main study was conducted over the entire 1972 school year. Sophomore students were assigned randomly to six classes (about 180 students) of business arithmetic and then the classes were randomly assigned to experimental and control condictions. Attrition reduced the sample size to about 100 students at the end of the year. Two teachers plus the researcher conducted the classes -- each taught one experimental and one control section. At the beginning of the year, all students were given the Aiken Revised Math Attitude Scale and the New York Arithmetic Computation Test. The classroom drill material consisted of problems involving that basic four arithmetic operations, with the experimental classes being taught how to use calculators and then using them for drill, while the control students worked the same drill problems by hand. At the end of the year, students were retested with the same measures plus the departmental final examination that emphasized business arithmetic concepts. However, students in the experimental classes (on alternate days), worked the computation test both by hand (one form) and with the use of the calculator (second form). Control students only did hand work.

Analysis of covariance was used with the attitudinal data, analysis of variance for the computational data, and t-tests for the final examination concepts test data.

4. Findings

For attitudes, no differences were found between the experimental and control classes, or between the beginning and end of the school year. For computations, experimental classes did better than the control classes only when they were allowed to use calculators on the posttests. Also, there was beginning-to-end-of-year improvement for both groups. On the concept-oriented final examination, no differences were found between the experimental and control groups.

5. Interpretations

Two possible explanations for the lack of finding attitudinal differences were given: first, the same form of the attitude survey was given during pretesting and posttesting, hence the memory effect produced more consistency of response; second, students felt that giving positive attitudinal responses might influence their grades and, hence, such responding could offset effects due to calculator use. No real explanation was offered for some of the no-difference findings on the cognitive measures.

Critical Commentary

Three points of concern need to be considered when interpreting the results from this study. First, attrition from the beginning to the end of the study was nearly 50 percent, and there were no data presented concerning the type of student who dropped out in both the experimental and control groups. One might speculate that the weakest students left and the remaining better students would have benefited less from calculator intervention. Second, use of calculators outside of the classroom is still a real possible contaminating factor even if students in the control group say they don't have calculators in the home (which Fischman inquired about). It would not take that many control students using calculators outside of class to "water down" the observable treatment effect. And third, and perhaps most important, there seemed to be no attempt to integrate carefully calculator usage into the business arithmetic instruction. If calculators are to be maximally beneficial, it is important to show students efficient ways to use them plus how calculators can add to the problem-solving process.

Hawthorne, Frank S. and Sullivan, John J. USING HAND-HELD CALCULATORS IN SIXTH-GRADE MATHEMATICS LESSONS. New York State Mathematics Teachers' Journal 25: 29-31; January 1975.

Expanded abstract and analysis prepared especially for the calculator Information Center by CLYDE A. WILES, Indiana University Northwest.

1. Purpose

This was an open-ended exploratory study that, in the authors' words, "was devoted to trying to discover how hand-held calculators could be used to advantage during sixth grade mathematics lessons."

2. Rationale

No rationale is presented.

3. Research Design and Procedures

The project began in October 1973 and extended throughout the school year. Forty-eight students from the sixth-grade classes in two New York communities were matched with other sixth-grade students presumably from the same schools on the basis of age, sex, and total mathematics achievement score. The achievement score was based on the New York Mathematics Test for Beginning Grade 6 administered in October 1973. This test has scales for concepts, computation, and problem solving, and was administered again in May to provide posttest comparisons.

The original two classes containing a total of about 68 students were provided with hand-held calculators with four functions and floating decimal point. The teachers of these classes were to try to discover how (and if) the calculators could enrich, supplement, support, and motivate the regular program. Teachers specifically were not to change the programs to fit the calculator and were to make sure that the use of calculators did not cause a lost of computational skill. The school principals supervised the prroject and all tests were to be taken without using the calculator. Nothing of the experience of the students not in the project is reported.

Although standardized tests were administered, the authors agreed that subjective reports of the teachers, authors, and administrators would provide the primary measures for evaluation. The standardized tests were

considered to provide a supportive, general screening type of evaluation.

4. Findings

The findings based upon subjective reports are not simply organized, but include the following:

a. Students experienced no difficulty in learning to use the calculators.
b. A high level of student interest was maintained throughout the year.
c. Calculators were useful for checking answers.
d. Students found calculators "extremely helpful in working with verbal problems."
e. Students were encouraged to explore topics not usually studied extensively in sixth grade.
f. Students gave increased attention to decimal fractions and the relationship between common and decimal fractions.

Though the importance and value of the standardized test data were discounted, it was reported that the students using calculators had significantly higher ($p < .02$) scores for both concepts and computation, while the performances for problem solving were virtually equal for both groups.

It was noted with some surprise that the standardized measure of problem solving did not favor the calculator group, in spite of the evident enthusiasm of this group for solving and creating complicated verbal problems during the course of the project.

5. Interpretations

The authors cautiously wrote that the design of the study and explorative nature of the project prevented strong conclusions concerning the effects of calculators. They also point to the enthusiasm of the teachers and the novelty of the calculators as confounding variables.

It was concluded that "the calculator can be used to advantage in sixth grade classes," and while it is not believed that "calculators have any great inherent ability to support and motivate mathematical study" . . . "with the strong direction of capable teachers, much can be accomplished."

Critical Commentary

Reactions to this exploratory study include:

a. This was a cautious exploration of the effects of simply making

calculators part of the sixth-grade mathematics curriculum without systematically modifying the content goals and objectives. The interpretations of the study are supported by the data provided.

b. From a negative point of view, it is apparent (while the authors do not say so) that certainly this use of calculators had no deleterious effects on standard achievement measures.

c. The doubts expressed about unspecified similar advantages occuring in primary grades seem to be pure conjecture.

d. The lack of differences favoring the calculator group for problem solving is interesting. The authors offer no explanation or conjectures about this unexpected finding.

I would hazard a conjecture or two:

a. The motivation to solve and create verbal problems was attributed to the calculators themselves, but calculators were not allowed during testing. It may simply be that the motivation to attempt these or to persevere to a solution was removed with the calculators, and the loss of motivation simply resulted in lower scores.

b. Or, it may be that the problems solved and created with great enthusiasm had no substantive relationship to the verbal problems on the achievement test.

To clarify the matter we need to know the nature of the verbal problems studied, solved, and tested. It may be that power testing at different times with and without calculators and with problems of specified types would give insight into motivation factors.

Hopkins, Billy Lynn. THE EFFECT OF A HAND-HELD CALCULATOR CURRICULUM IN SELECTED FUNDAMENTALS OF MATHEMATICS CLASSES. (Unpublished Doctoral Dissertation, University of Texas at Austin, 1978.)

Expanded abstract and analysis prepared especially for the Calculator Information Center by EDWARD C. BEARDSLEE, Seattle Pacific University.

1. Purpose

The study was designed to determine if the use of a calculator-based curriculum with a classroom set of hand-held calculators would have an effect on student achievement in computation, achievement in problem solving, and attitude towards mathematics.

2. Rationale

With the increased availability and decreased cost of hand-held calculators, teachers are faced with many decisions regarding classroom use of these devices. Much of the previous research has been on the use of hand-held calculators as a supplement to the regular curriculum, not as an integral part of the curriculum.

The ninth-grade general mathematics course would be an appropriate place to include a calculator-based computation curriculum since many students enrolled in a ninth-grade general mathematics course (a) will not be taking additional mathematics courses, (b) have negative attitudes toward mathematics, and (c) lack the basic computational skills. Using a calculator may also free students from the burden of computation and allow them to concentrate on the problem itself, which could improve problem-solving ability. Hopkins reports that he could locate no studies involving ninth-grade general mathematics that compared the non-use of calculators with the use of calculators when an instructional curriculum for using the calculator is provided, although there have been some studies of this type with other subjects or grade levels.

3. Research Design and Procedures

Ten hypotheses were developed to test the effect of the calculator on achievement, problem-solving ability, and attitude toward mathematics. The instruments used were: the computation portion of the Stanford Achievement Test, Intermediate Level I to measure achievement in computation;

the application portion of the Stanford Achievement Test, Intermediate Level II to measure achievement in problem solving; and the PY407, PY408, PY409, and PY410 scales of the Form 9151 Attitude Test, developed by the School Mathematics Study Group to measure attitudes toward mathematics.

The independent variables were the calculator or non-calculator designation of the treatment groups and the use or non-use of calculators on the posttest. Concomitant variables were pretest means on computation achievement, on problem-solving achievement, and in attitudes toward mathematics. The dependent variables were posttest means on computation achievement, on problem-solving achievement, and on attitudes toward mathematics.

The experimental design was similar to the type classified by Campbell and Stanley (1963) as a Nonequivalent Control Group Design.

Two parallel sets of instructional materials to teach estimation, computation, and problem solving using the four arithmetic operations on whole numbers to ninth-grade general mathematics students were developed. One set of materials was designed to be used with a classroom set of calculators and the other to be used with paper and pencil only. Both sets of materials included extensive teacher guides and student pages. The teacher's guide included outlines of each lesson and examples for teacher presentations. The unit (for both treatment groups) was designed to take 22 days of class time. The first two days and the last two days were devoted to achievement and attitude testing, leaving eighteen days for instruction.

A pilot study was conducted during the summer of 1977. The pilot study included the instructional materials and all of the pretest and posttest components. As a result of the pilot, the instructional materials were revised.

Twelve classes of the Fundamentals of Mathematics course "Basic Mathematics" in a Texas urban district were assigned to one of two treatment groups during the Fall Quarter of 1977. Six teachers participated in the study, each having one class in the calculator treatment and one class in the non-calculator treatment. Three high schools were involved, each having two participating teachers. One-hundred-sixty-seven students were used in the study, 83 in the calculator treatment and 84 in the non-

calculator treatment. Students in both groups were given pretests in mathematics achievement and attitude. Both treatment groups were given units of instruction on estimation, computation, and problem solving using the four arithmetic operations on whole numbers. The calculator group used a classroom set of hand-held calculators in instruction. The non-calculator group used paper and pencil only. Posttests in mathematics achievement and attitude were given to both groups. Half of each group took the achievement posttest with a hand-held calculator as an aid. The other half of each group took the achievement posttest using paper and pencil only. The resulting data were analyzed using analysis of covariance.

4. Findings

Hopkins found no significant differences between the two treatment groups on computation achievement, but there was a significant difference in problem-solving achievement. Also, the group using calculators on the posttest scored significantly higher on both computation achievement and problem-solving achievement. There was an interaction effect between treatment and calculator use on the posttest in problem-solving achievement. The group in the non-calculator treatment who took the posttest using a calculator scored higher in problem-solving achievement than the group in this treatment who took the posttest without a calculator. The group in the calculator treatment who took the posttest with a calculator scored lower in problem-solving achievement than the group in this treatment who took the posttest without a calculator.

There was no difference between the two treatments on the attitude measures.

5. Interpretations

No evidence was found to indicate that the use of a calculator-based curriculum will increase student achievement in computation. The results indicate, however, that students would not be expected to lose skills in computation if they were given instruction using hand-held calculators, as gains in computation achievement were consistent with gains of students not using calculators in instruction. The gains were consistent even when calculators were not available on the test.

Evidence was found to indicate that the use of a calculator-based curriculum with a classroom set of hand-held calculators does have a positive effect on student achievement in problem solving. Students receiving the calculator treatment did perform significantly better in problem solving than students receiving the non-calculator treatment.

Based on the evidence of this study, the investigator concludes that the use of hand-held calculators in instruction gives students in ninth-grade general mathematics more opportunity to develop problem-analyzing and attack skills.

No evidence was found to indicate that the use of a calculator-based curriculum with a classroom set of hand-held calculators has an effect on students' attitudes toward mathematics.

The following are implications for education, which Hopkins based on the results of his study:

(a) Students in ninth-grade general mathematics can improve their skills in computation and problem-solving achievement using a calculator-based curriculum in learning.

(b) Students in ninth-grade general mathematics who use a calculator-based curriculum in learning may acquire greater achievement in problem solving than students who use a non-calculator curriculum in learning.

(c) Students in ninth-grade general mathematics who are allowed to use hand-held calculators while taking tests achieve higher scores in computation and problem solving than students who are not allowed to use calculators on tests.

(d) Students in ninth-grade general mathematics who use a calculator-based curriculum in learning do not appear to lose computation skills when tested using paper and pencil only.

Critical Commentary

The result that students with calculators performed better on the posttest than those students without calculators should not be too surprising. The computation portion of the Stanford Achievement Test was not intended to be used with calculators. Once a student understands how to operate a calculator, many of the computation exercises could easily be done. However, careful perusal of Hopkins' study leaves few questions

unanswered. The hypotheses, design, and interpretations were carefully done. To this abstractor, Hopkins' work represents one of the more useful studies in the area of using calculators in instruction, because he asked some significant questions, piloted his study prior to the final investigation, then carefully analyzed and interpreted his results. Hopkins' finding that calculators can help to improve problem-solving skills is one that should stimulate additional researchers, as well as curriculum developers, to prepare calculator materials to teach problem-solving skills.

Hutton, Lucreda Ann Williams. THE EFFECTS OF THE USE OF MINI-CALCULATORS ON ATTITUDE AND ACHIEVEMENT IN MATHEMATICS. (Indiana University, 1976.) Dissertation Abstradts International 37A: 4934; February 1977. [Order No. 77-3347]

Expanded abstract and analysis prepared especially for the Calculator Information Center by JAMES J. HIRSTEIN, University of Illinois.

1. Purpose

The purpose of the study is to investigate the effects of the use of the mini-calculator on student attitude and achievement during a segment of the second semester of a ninth-grade Algebra I course.

2. Rationale

There are conflicting opinions regarding the role of mini-calculators in the mathematics classroom. There is disagreement among educators as well as within the general public. Therefore, the effects of using mini-calculators need to be established. All of the literature reviewed dealt with using calculators with low-achieving students. There is a need for studies of using the mini-calculator with average and high-achieving students.

3. Research Design and Procedures

The study was done using three teachers of Algebra I classes in two schools in Indiana. Each teacher taught one control class and one class with the calculator as a teaching aid (i.e., the use of a calculator was incorporated into lectures). Two of the teachers also taught a class using the calculator as a student aid (i.e., the calculator was available, but not explicitly used in instruction). The classes all covered a unit on "powers, roots, and radicals" and the study was done during a four-week period during the second semester.

A battery of three tests chosen from the NLSMA Population Y reports were used as a pretest and repeated as a posttest after instruction. Two attitude scales, the Pro-math Composite and the Math--Fun vs. Dull, were included. Achievement was measured by one of the NLSMA Mathematics Inventory forms; a subscale concerning roots, powers, and radicals was selected from the items for this experiment.

Each teacher was considered separately in the analysis. For each of the three tests, the control group was compared with each experimental group on pretest scores using a t-test. Then a similar t-test analysis was done using gain scores (posttest minus pretest) on each scale. Subjective comments were solicited from all teachers and students participating.

4. Findings

None of the achievement scores, neither pretest nor gain, showed any significant differences between the experimental and control calsses of a single teacher. Only one attitude sclae, gain on Fun vs. Dull, shhowed significance ($p < .05$) for one teacher in favor of an experimental (calculator as a student aid) class.

Subjective statements by students indicated that they thought using the calculator was enjoyable and helpful. The teachers reported that the calculators seemed to motive students and that no instructional time was lost in order to include the calculator component.

5. Interpretations

Although none of the achievement gains statistically favors either class, the greater gains were always made by the classes using calculators. This, along with student enjoyment, indicates a "judgment in favor of calculator use in the mathematics Algebra I classroom." At least, there is no evidence here to support banning calculators in Algebra I.

Critical Commentary

A number of questions are raised about this study:

a. There is no indication of baseline data for the attitude scales. There is a set of pretest means with statistics to say the class means do not differ, but do these numbers indicate good or bad attitudes before the treatment? This information is critical for interpretation. It is doubtful that one month with a calculator would affect overall poor mathematics attitudes, and it is ridiculous to expect improvement of good attitudes.

b. Pretest data for achievement are not even reported. There is no way of comparing the classes with respect to entering knowledge.

c. Little attention was given to classroom variables. Treating three teachers as three separate analyses does not control teacher variables. Furthermore, no effort to monitor the teachers' adherence to suggested classroom procedure is indicated.

d. There is a natural correlation between pretest and posttest scores that is ignored by treating Pretest and Gain in separate analyses. The design used in this study clearly calls for a repeated measures analysis.

Jamski, William Donald. THE EFFECT OF HAND CALCULATOR USE ON THE ACHIEVEMENT OF SEVENTH GRADERS LEARNING RATIONAL NUMBER-DECIMAL-PERCENT CONVERSION ALGORITHMS. (Indiana University, 1976.) Dissertation Abstracts International 37A: 4934-4935; February 1977. [Order No. 77-3349]

Expanded abstract and analysis prepared especially for the Calculator Information Center by J. F. WEAVER, The University of Wisconsin-Madison.

1. Purpose

It was the intent of this investigation "to determine the effect of the hand calculator in assisting the middle school student who has the prerequisite skills in terms of achievement while learning the various rational number-decimal-percent conversions algorithms . . . [and] . . . the interaction effect [if any] between student ability and calculator use." Also, "the use of the hand calculator was to be compared on the effect of achievement with the various conversions."

2. Rationale

". . . the topic in question, the conversion algorithms between simplified rational numbers, decimals, and percents had not been explored with respect to calculator utilization."

3. Research Design and Procedures

Participating students were from six middle school "Level II' classes, three of which were randomly chosen to be C (calculator) classes and the other three to be NC (no calculator) classes. All classes were taught by the same experienced teacher.

On the basis of results from an eight-item pretest (NLSMA Form 7S-3, Test D, pertaining to whole-number division [with two-digit divisors in seven of the eight items]), students within each class were partitioned into Hi, Mid, and Lo "ability" groups. This pretest was administered to 162 students approximately three weeks prior to the beginning of a three-week instructional period.

Treatments during the instructional period were based closely upon material in Holt School Mathematics, Grade 7 (1974), covering six types of conversions:

a. conversion from simplified rational to equivalent decimal form,

b. conversion from decimal to equivalent simplified rational form,

c. conversion from percent to equivalent decimal form,

d. conversion from decimal to equivalent percent form,

e. conversion from percent to equivalent simplified rational form, and

f. conversion from simplified rational to equivalent percent form

(where simplified rational embraced that which many persons might term "fractions" [or "fractional"] and "mixed" numerals expressed in "lowest terms"). The essential difference in treatments between the C and NC classes was the use of calculators (Rockwell 10R) in the development and use of conversion algorithms by students in the C classes, with no calculators being used in the NC classes.

A six-part posttest, consisting of six items (exercises) for each of the six types of conversions, was administered at the end of the three-week instructional period and re-given approximately five weeks after its first administration. LC students were permitted to use calculators on the first but NOT on the second administration of the posttest. Complete sets of test scores were available for 136 of the 165 students who were pretested.

Data analyses focused upon these four null hypotheses:

"H_1: There is no significant difference in achievement among students using hand calculators and those not using them."

"H_2: There is no significant difference in achievement due to the interaction of student ability and hand calculator use."

"H_3: There is no significant difference in achievement between high-ability students not using hand calculators and those in the low-ability group using them."

"H_4: There is no significant difference in achievement approximately one month after the post-test between the experimental group, not using hand calculators, and the control group."

4. Findings

On the pretest there was no significant ($\alpha = .05$) difference in means between C-students' scores and NC-students' scores.

In order to "test" H_1 and H_2, an independent 2 (treatment) x 3 (ability level) ANOVA was run for each of the six conversion types, using as the criterion measure the scores on the appropriate six-item part of the

posttest (first administration). Only one of the six conversions (simplified rational to equivalent decimal form) showed a significant main effect due to treatment; each of the six conversions showed a significant main effect associated with ability level; no significant interaction effects were observed.

A significant difference was observed between LoC and HiNC performance (first administration of posttest) for each of the six conversion types (H_3).

In connection with H_4, on the second administration of the posttest no significant difference between C and NC performance was observed for any of the six conversion types.

"As a measure of reliability, two Pearson product-moment correlations were computed between the post-test and re-test scores for each conversion. One was done for NC and the other for C." The NC coefficients ranged from .57 to .94; the C coefficients, from .55 to .78.

5. Interpretations

Based upon the criterion of achievement (as measured by the instruments used in this investigation):

". . . calculator use in general could not be judged to be successful with simplified rational-decimal-percent conversion algorithms."

"At this level and with this type of topic . . . there was no reason to segregate the use of hand calculators by ability groups. . ."

". . . the emphasis of calculator use with slow learners should not be geared toward competitive achievement levels with superior students."

". . . hand calculators did not provide the means to bridge the ability gap among stududents with this topics."

Critical Commentary

I have many misgivings regarding this investigation, ranging from the choice of prerequisite ability" criterion, through the use of univariate rather than multivariate analyses, to the investigator's interpretations and implications of findings -- some of which are obscured by the fact that page 64 of the dissertation was not included in the material sent to University Microfilms for reproduction.

The following fact makes it impossible for me to even consider any further commentary: Although 18 ANOVA tables are presented, nowhere

the exception of Table 23) in either the body of the research report or its Appendixes can I find any concomitant data that give me a picture of student performance, either by treatment or "ability" level for any of the six conversion types, on either the first or second administration of the posttest. Failure to include such information in a dissertation is inexcusable and, I feel, professionally irresponsible.

Jones, Edris Whitted. THE EFFECT OF THE HAND-HELD CALCULATOR ON MATHEMATICS ACHIEVEMENT, ATTITUDE AND SELF CONCEPT OF SIXTH GRADE STUDENTS. (Virginia Polytechnic Institute and State University, 1976.) Dissertation Abstracts International 37A: 1387; September 1976. [Order No. 76-19,855]

Expanded abstract and analysis prepared especially for the Calculator Information Center by CLYDE A. WILES, Indiana University Northwest.

1. Purpose

The purpose of this study was to investigate the effects of introducing the hand-held calculator into the sixth-grade mathematics curriculum. While a number of sub-hypotheses were tested, including some related to sex differences, the central hypothesis was:

> There is no difference in the mathematics achievement, attitude and self-concept of students using he hand-held calculator during the learning period and students performing without . . .

2. Rationale

The decline of standardized test scores in mathematics and the easy availability of inexpensive hand-held calculators were both noted. It was conjectured that the introduction of these machines, in a systematic and large-scale way, may improve the situation. However, the probable effects of such an action are not known. A review of current litterature revealed evidence inadequate to support either course of action. Hence the need for the study.

It was conjectured that if introduction of the calculator increased achievement, this in turn may have a positive effect on general attitude toward arithmetic and self-concept.

3. Research Design and Procedures

a. Subjects

The study involved the students from three sixth-grade classes in one school in Norfolk, Virginia and three sixth-grade classes from another in Portsmouth, Virginia. The population was characterized as multi-ethnic and as from low to middle socio-economic status. They were special in no other way. Two of the classes from each school were

randomly selected to work with calculators. All four of the classes using calculators were identified as an experimental group, while the children of the remaining two classes were identified as a control group. The experimental group thus contained 58 girls and 55 boys, while the control group consisted of 33 girls and 25 boys.

b. Instruction

Lessons specifying objectives to be studied on given days were created. There were 40 lessons and 41 instructional days thus specified. The lessons all related to computations and applications of decimal numbers and common fractions, with some attention to metric measures and percent. Homework was assigned at parental insistence; homework reflected the classwork. Calculators were not provided for homework, however. All classes were to complete the same lessons except that the classes in the experimental group were provided with one day for orientation to the calculator. The experimental subjects were provided with battery-operated, four-function, floating decimal point calculators and were "encouraged to use them as often as possible" during the mathematics class periods except for testing. The control classes were not allowed to use calculators during class time.

It can be noted here that 10 of the control subjects later reported using calculators for homework, but that the exclusion of their data had no significant effects on the findings.

The six teachers were given a one-day orientation to the project before it began and came to weekly meetings thereafter to insure that instruction was proceding as planned. Teachers were to keep a record of the amount of time children actually used the calculators in the experimental classes, but these data are not reported.

c. Tests and Measures

Two forms of standardized achievement tests were used to measure pre- and post-instruction achievement. These tests provide a computation score, a mathematics concepts score, and a total mathematics score. The concepts questions are identified as measures of "understanding of basic numeration and mathematical operations as well as knowledge and application of concepts in measurement, geometry and problem solving." The computational questions are said to measure "ability to add, subtract, multiply and divide whole numbers." No specific mention is made of either decimal or common fractions.

Attitude toward the learning of mathematics was measured by Dutton's (1968) Attitude Toward Arithmetic Scale, and self-concept by Piers (1969) Piers-Harris Children's Self Concept Scale.

d. Analysis of Data

The data were analyzed by analysis of covariance using the pretest achievement scores as covariates. Although there are dependencies among the posttest concepts, computation, and total achievement scores, they were analyzed independently. Independent analyses were also conducted for the attitude and self-concept scales. The independent variables tested for significance were: experimental vs. control and boys vs. girls. Some data from the attitude test could not be analyzed in this way, and these data were summarized in appropriate categories.

4. Findings

The experimental group had significantly greater achievement than the control group in terms of total achievement, computation, and concepts. A significant difference for concepts scores was found within the experimental group that favored the girls. No differences were found involving attitude or self-concept scores.

Five items of the attitudinal test were open-ended. These data were summarized but no clear findings came from them.

5. Interpretations

It was concluded that significant improvement in mathematics achievement including both concepts and computation did occur. Moreover, the sex of students was not a contributing factor except with concepts scores. Attitude and self-concept were unaffected.

It was asserted that these findings support the contention that the hand-held calculator can be used as a tool to

"(1) discover new ways of utilizing the instrument

(2) reduce boring, tedious drill and

(3) serve as a motivational instrument."

Finally, it was asserted that "the most important use . . . gleaned from the experiment was that the hand-held calculator could be used to personalize instruction." A number of recommendations then are offered for further research, noting pointedly that "further research is needed

before making major decisions relative to complete usage of the hand-held calculator."

Critical Commentary

This study seems to have arisen out of an administrative need to make a decision about large-scale introduction of calculators into the mathematics curriculum of the elementary school. The answer provided by this study is a definite "maybe". The administrator or researcher drawing information from this study should note a number of factors:

a. The clear statement of instructional intent and time devoted to each lesson and concept are most helpful in understanding any action research project and this is no exception.

b. The use of measures of indirect outcomes is to be commended to all. Although no differences were found in any of those investigated here, that alone can be an important finding.

c. This reviewer was troubled by a number of things, but primarily by a serious doubt about test validity. One wonders how the test measures the objectives taught. The overlap of the test content with the content of instruction is apparently small. The computation test measures only whole number operations, while the instruction was chiefly concerned with decimals and common fractions. It is not clear that the concepts test dealt fairly with instructional content, either. It may be that the achievement test was inaccurately or incompletely described, but if not, the implications of the study should be adjusted in some way.

d. Whatever the differences really were, what is the real cause? The Hawthorne effect was "deemed inappropriate" for consideration in this study, but ten subjects from the control group admitted using calculators at home, and the final conclusions of the study glow with considerations commonly associated with novelty and variability. One wonders how many of the children in the experimental group obtained or used calculators apart from the controlled situation.

e. Why were sex differences investigated and what is to be made of the one apparently uninterpretable finding?

f. Statistics customarily reported for ANCOVAs are not presented.

The obvious dependencies among the various variables are not noted, much less discussed. The analysis was done with individuals as the unit of observations without even noting the hazards associated with this. It seems probable that the analysis was based upon expert advice, but that the rationale for it was not appreciated. All this places additional limitations upon the findings and interpretations of the study.

Finally, it seems to this reviewer that the interpretations and recommendations of this study, while consistent with the findings, should be acted upon with great caution. The administrator or teacher favorably disposed to introducing calculators into the curriculum is encouraged by this study. However, the author's call for further investigation is well made.

Kasnic, Michael James. THE EFFECT OF USING HAND-HELD CALCULATORS ON MATHEMATICS PROBLEM-SOLVING ABILITY AMONG SIXTH GRADE STUDENTS (Oklahoma State University, 1977.) Dissertation Abstracts International 38A: 5311; March 1978. [Order No. 7801276)

Expanded abstract and analysis prepared especially for the Calculator Information Center by DONALD J. DESSART, The University of Tennessee-Knoxville.

1. Purpose

The primary purpose of this study was to determine whether or not the use of hand-held calculators in the classroom would lead to the improvement of the mathematical problem-solving ability among sixth-grade students.

2. Rationale

Hand-held calculators are rapidly becoming a popular tool for computation in nearly all walks of life. Their use in the schools is almost a foregone conclusion. The primary interest at the present time is the discovery of their most effective uses with children. Since problem solving is a much-sought-after goal in schools, it is most reasonable to study the usefulness of hand-held calculators in promoting the problem-solving abilities of children.

3. Research Design and Procedures

In this study, four schools were randomly selected from among 13 schools in a large suburban school district. All of the sixth graders in the four schools were tested for problem-solving abilities with the California Achievement Test, Level 3, Form B, Mathematics Concepts and Problems subtest. These students were then classified into one of three ability levels: low, average, or high. Ten students were randomly selected from each of the ability levels in each of the four schools for participation in the experiment.

At this point the four schools were randomly assigned to one of the following usage groups:

a. To use calculators for practice but not on the posttest.

b. To use calculators for practice and also for the posttest.

c. To use paper-pencil only for practice and also for the posttest.

d. To act as a control by not practicing problem solving but taking the posttest.

The treatment consisted of the students studying a series of progressively more difficult problem-solving questions which were designed to improve their problem-solving skills. The total treatment covered nine 50-minute sessions, which was followed by an 86-item problem-solving posttest. The posttest was made up of items which tested the ability of students to determine which computational procedures were necessary to solve the problems as well as the ability to carry out the computations. These were subjected to separate analyses.

The analysis of the data included determining Pearson product-moment correlations between the number of completed practice problems and the number of correct responses on the posttest, calculating a treatment-by-levels analysis of variance F ratio among the groups with the posttest scores, and finding non-correlated t scores to determine whether or not differences existed between the group using calculators on the posttest and the remaining three groups.

4. Findings

The analysis of the data resulted in the following findings:

a. The use of the calculators with practice problems did not result in the students completing more practice problems than those who did not use calculators.

b. The more practice problems completed by students with calculators the more likely they were to solve problems on the posttest.

c. The use of calculators by high and average ability students on the posttest did not result in their solving more problems than comparable students who did not use calculators on the posttest. A similar finding was true for low ability students.

d. The use of calculators did result in average and low ability students solving a greater number of questions that determine computation than comparable students who did not use calculators.

e. The high ability control group solved a significantly greater number of problems than every low ability group except the low ability group who used calculators on the posttest.

5. Interpretations

A most comforting conclusion of this study deals with the results for low-ability students in which it was found that the use of the calculators helped them in competing more successfully with higher ability students. The disappointing conclusion that calculators did not appear to substantially aid average and high ability students may temper the claims of those advocates who may overvalue the hand-held calculator as a classroom tool.

Critical Commentary

This study represents a very careful design in which many of the flaws common to much of educational research have been removed. Randomization was employed exceedingly well, and the treatments were meaningful and carefully controlled. Perhaps the most serious concern is the very short treatment time, as nine 50-minute sessions provide insufficient time to observe any but transitory effects. It would seem that the investigation has uncovered a promising finding in relation to low-ability students; perhaps more time could be spent in pursuit of that lead by other researchers.

Laursen, Kay William. USE OF CALCULATORS IN HIGH SCHOOL MATHEMATICS: A STUDY COMPARING ACHIEVEMENT, ATTITUDE AND ATTENDANCE OF GENERAL MATHEMATICS STUDENTS WHO USED CALCULATORS WITH STUDENTS WHO DID NOT. (Brigham Young University, 1978.) Dissertation Abstracts International 39A: 733; August 1978. [Order No. 7813828]

Expanded abstract and analysis prepared especially for the Calculator Information Center by GRAYSON WHEATLEY, Purdue University.

1. Purpose

The purpose of this study was to determine the effects of calculator use by high school general mathematics students on achievement, attitudes, and attendance.

2. Rationale

Since low-cost calculators are readily available, educators and parents are embroiled in a controversy over the use of these technological wonders in schools. This study was undertaken to provide information for educators on the effect of calculator use in high school general mathematics classes.

3. Research Design and Procedures

Eighteen general mathematics classes (505 pupils) from five Utah high schools were identified, with nine classes assigned to a calculator treatment and nine serving as a control. Availability of calculators at the high school level and teacher interest were factors in the assignment. Data from 64 percent of the pupils were available for analysis.

The students in the experimental group (E) were provided with four-function calculators to be used as an aid to complete assignments and work test problems. The control group studied the same content (whole numbers, decimal and fraction computations, percents, interest, consumer applications, and measurement), but without calculators. The treatment period extended over the Fall semester, 1977-78.

A 65-item multiple-choice mathematics achievement test (KR-20 coefficient = .92) written by the experimenter was used as a pretest and a posttest. The Mathematics Attitude E Scale (Aiken, 1974) also was used as a pre- and post-measure. The mean number of absences for each class

was computed. The experimental group used calculators on the posttest but not the pretest.

A 2 x 2 (Treatment, Sex) analysis of covariance with the pretest scores as the covariate was applied to the mathematics achievement posttest scores. The individual was treated as the experimental unit. The attitude data were analyzed in a similar manner. Attendance data were analyzed by a 2 x 2 (Treatment x Sex) analysis of variance with number of absences in first 80 treatment days as the dependent variable.

4. Findings

The experimental group scored significantly higher than the control group [$F(1,320) = 35.28$, $p < .01$], while the sex difference and interaction were nonsignificant. There was no treatment difference in attitude, but there was a significant sex difference in favor of males [$F(1,302) = 13.82$, $p < .01$]. There were no significant attendance differences. After the study, five of the six experimental group teachers stated that they would prefer to teach general mathematics with calculators.

5. Interpretations

The use of calculators by general mathematics students resulted in significant improvement in achievement. The difference was attributed to the elimination of computational errors and increased willingness of the students to attack more complex problems, both made possible by the calculator. The calculator does not change attitudes towards mathematics.

On the basis of these findings, the author recommends that calculators be made available to general mathematics students. The author recommends that a similar study be conducted with two experimental groups, one being tested without the calculator.

Critical Commentary

The findings of this study must be interpreted with great care. As the author notes, the absence of an experimental group that took the achievement test without calculators obviates the cause of the posttest treatment difference. Was the difference due to treatment or was it due to calculator availability? Actually, for both E and C, the achievement test gains were small for a semester-long treatment. An examination of

the pre- and posttest means found in the appendix reveals that for C the gain was 6.7 and for E it was 10.6. Thus we see that the E group had only four more problems correct than the C group. Given that they had the advantage of a computing device during testing, this difference may not be educationally significant. The use of an inappropriate experimental unit (individual instead of class), together with the absence of random assignment, further clouds the interpretation. Of major importance is the type of use made of calculators in mathematics classes. We will not have gained much if the calculator only serves as a substitute for computation and an answer-checker, while the curriculum otherwise remains the same. It is critical that the effectiveness of calculators be judged with a curriculum incorporating calculators as an instructional tool.

Lawson, Thomas James. A STUDY OF THE CALCULATOR'S AND ALTERED CALCULATOR'S EFFECT UPON STUDENT PERCEPTION AND UTILIZATION OF AN ESTIMATION ALGORITHM. (State University of New York at Buffalo, 1977.) Dissertation Abstracts International 39A: 647; August 1978. [Order No. 7813985]

Expanded abstract and analysis prepared especially for the Calculator Information Center by GRAYSON WHEATLEY, Purdue University.

1. Purpose

The purpose of the study was two-fold: (a) to determine the effect of calculator use on students' desire and ability to estimate as part of a problem-solving strategy and (b) to ascertain students' perceptions of the educational value of calculators.

2. Rationale

With the widespread use of calculators in schools, critics argue that students will lose the ability to compute and become too dependent on the calculator. Since most persons rank estimation as an important mathematical ability, information on the effect calculators have on estimation is needed. Further, specific methods of teaching estimation skills should be evaluated.

3. Research Design and Procedures

The sample for this study consisted of 271 seventh-grade students from a suburban-rural junior high school. Students were randomly assigned to one of three treatment groups: (a) a group that was restricted to paper-and-pencil methods, (b) a group that used calculators to compute, and (c) a group that used calculators with the operation keys masked. Within each treatment group, three ability levels were determined using the New York State Pupil Evaluation Program computation scores.

The criterion for inclusion was previous demonstration of a minimal competency (80 percent) knowledge of place value and computation in the decimal numeration system. [The reviewer does not understand how this criteria could have been applied.] The procedures were as follows: All students were taught estimation skills during mathematics class for a three-day period. The data collection occurred during one class period five days after the last estimation lesson. Pupils were randomly assigned

to one of three treatment groups: calculator, altered calculator, or paper and pencil. All students took a 20-item decimal number estimation test without calculators (pretest), then worked 16 problems by the method designated (calculator, altered calculator, or paper and pencil), followed by a 20-item decimal estimation posttest (a reordering of the items in the pretest). The pretest consisted of five addition (316.7 + 453.9), five subtraction (84.6 - 17.7), five multiplication (6.3 x 7.9), and five division problems (50.6 ÷ 0.4).

The entire data collection duration varied from twenty to forty minutes, including pretest, treatment, and posttest. It can then be inferred that the "treatment" lasted from five to ten minutes.

It is reported that a two-way MANOVA model was used for data analysis. The study reports analyses for ability and treatment in separate tables, with no mention of interactions. Further, the univariate results are interpreted with no mention of the multivariate F ratios. For the ability analysis, eight subtest variables are entered (pre-post scores) for each operation, while for the treatment analysis four change scores are treated as the dependent measures. Subsequently, pre and post time to completion are analyzed independently for ability and treatment. The number of errors on the interim experience were also analyzed using multivariate techniques. In the two days following the posttest, a total of 29 students from the calculator and altered calculator groups were interviewed to ascertain their reaction to the experience and calculators in education.

4. Findings

The reported findings of this study were:

a. Students of better computational ability tend to be better estimators ($p < .001$).

b. There was no difference between the mean change scores of the three treatment groups.

c. The use of unaltered calculators resulted in fewer computational errors on the interim experience.

d. Students with or without calculators do not generally use skill of estimation to verify answers regardless of the computational method (paper and pencil or calculator).

e. Through pupil interviews it was concluded that the seventh-grade pupils have a perspective on the limitations of the calculator equivalent to that of adults.

5. Interpretations

The interim experience did not result in improved estimation scores. Pupils provided with calculator-assisted interim work experience, using either regular or altered calculators, did not significantly improve their estimation performance over those who simply computed using paper and pencil. The researcher suggests that a longer experience might have a positive effect on estimation scores. Pupils are limited in their ability to estimate by their computational ability. The use of calculators did reduce the number of computational errors made on the interim experience. Results from the pupil interviews suggest that seventh-grade pupils recognize the limitations of calculator use, feel that one should not become dependent on calculators, and are likely to make sensible uses of calculators.

Critical Commentary

This study is seriously flawed in conceptualization, design, and data analysis. Further, the report is so sketchy that the reader is hard-pressed to know what happened and how the data were analyzed. The entire study was conducted in the 20 to 40 minutes of a single class period. Great care must be exercised in interpreting findings based on such a brief period of time. It seems particularly inappropriate to attempt an evaluation of calculator use based on, at most, 40 minutes of experience.

The rationale for including an altered calculator treatment is not made clear. It is difficult to see how value can be derived from having pupils compute with a calculator where the operation keys have been masked.

It appears from the report that multivariate techniques have been misapplied. Interpretation of univariate F values are made without reference to multivariate values. No mention is made of any interaction. In fact, it appears that ability, treatment, and time are analyzed separately.

There are numerous other problems in this study. Extreme caution must be used in viewing conclusions based on this study.

Lenhard, Rodger William. HAND-HELD CALCULATORS IN THE MATHEMATICS CLASSROOM AT STUART PUBLIC SCHOOL, STUART, NEBRASKA. (Montana State University, 1976.) Dissertation Abstracts International 37A: 5661; March 1977. [Order No. 77-4974]

Expanded abstract and analysis prepared especially for the Calculator Information Center by MARILYN N. SUYDAM, The Ohio State University.

1. Purpose

The intent was to determine whether mathematics students in grades 7 through 12 performed better on concepts or computation or changed attitudes by using hand-held calculators on tests.

2. Rationale

Calculators are becoming a part of life for many students today. Prices have declined. Therefore teachers should plan carefully designed experimental programs using the calculators in mathematics classrooms. The review of literature cited some [random] references in innovations in mathematics (television, unipacs, children's literature, retesting, and mathematics laboratories, with little indication of the relationship of these topics to calculators), attitudes, and use of calculators.

3. Research Deisgn and Procedures

The study was conducted during the first semester of 1975-76 in Stuart (Nebraska) High School. All students were exposed to calculators during the first week; they could practice with calculators during free time in the second week. Each mathematics class in grades 7-12 was randomly divided into two groups; the groups alternated using APF Mark 26 calculators (four operations, percentage key, memory) on tests administered in each class. Following each test, the Aiken-Dreger Attitude Scale (r = .94) was administered. Involved were 125 students in:

	N	tests	type
Math 7	29	10	teacher-made
Math 8	26	9	teacher-made
General Mathematics	19	8	accompanying text
Algebra I	21	8	accompanying text
Business Mathematics	15	8	accompanying text
Algebra II	3	8	teacher-made
Geometry	10	8	accompanying text
Trigonometry	2	8	teacher-made

Pre- and posttests measuring mathematics concepts and computation were:

grades 7-8 Stanford Diagnostic Arithmetic Test, Level II, Form W

grades 9-10 Stanford Tests of Academic Skills, Level II

grades 11-12 Stanford Tests of Academic Skills, Level II

Reliabilities for these tests ranged from .90 to .98.

Scores were compared with the t-test for independent samples and, when appropriate, the F-test and Duncan's test for multiple comparisons.

Students were observed to ascertain if they checked their work or if they had any unusual reactions as they took tests.

4. Findings

Sixteen null hypotheses were tested. No significant differences were found between experimental and control groups on (1) test scores, (2) number of concept errors, (3) number of computational errors, (4) attitudes toward mathematics, (5) time to finish test, (6) rank of students, (10) concept errors of poorer students, (11) computational errors of poorer students, and (12) attitudes of poorer students. When poorer students (T scores less than 45) were compared with better students (T scores greater than 55) on (7) number of concept errors, (8) number of computational errors, and (9) attitudes toward mathematics, the poorer students scored significantly lower. When grade levels were compared, no significant differences were found on (13) test scores and (14) number of concept errors; on (15), number of computational errors, the fewest were found in grades 8 and 12; on (16), time to finish test, the range of 17 to 41 minutes was significant.

On the standardized test administered pre- and post-treatment, significant differences were found in Math 7 for concepts, decimals and percentage, and number facts; all subtests in Math 8; and tests in Algebra I, General Mathematics, Business Mathematics, and Algebra.

Observations indicated that very little checking was done; the better students checked work whether they had calculators or not, while the poorer students tended not to check work. No unusual reactions during testing were noted.

5. Inaterpretations

Had the study been conducted for a longer period of time, there might have been a significant diffeence in test performance. The calculator

should have been motivational. However, the better students were interested in all phases of mathematics, while the disinterested remained disinterested. Differences in mathematics background and interest of students were considered reasons for subtest and grade level findings. A larger population, control of teacher effect, use of distinct experimental and control groups, and equal-sized enrollments were suggested as possible ways to improve the study.

Critical Commentary

That there were flaws in this study seems obvious. In addition to those suggested by the resarcher could be noted, for instance, (1) the administration of attitude scales following achievement tests, without note of the potential influence of the first on the second; (2) the use of nine tests in one class, so that experimental and control testings were not equal; (3) lack of any information on the content of the test or what use of calculators was made on them; (4) the exceedingly small N in two classes; (5) the random rationale and review of literature, which seemed symptomatic of the lack of depth in the study. This was action research, conducted with an available population as they used a new tool. The results must be accepted within severe limits.

Lowerre, George F.; Scandura, Alice M.; Scandura, Joseph M.; and Veneski, Jacqueline. USING ELECTRONIC CALCULATORS WITH THIRD AND FOURTH GRADERS: A FEASIBILITY STUDY. School Science and Mathematics 78: 461-464; October 1978.

Expanded abstract and analysis prepared especially for the Calculator Information Center by ROBERT E. REYS, University of Missouri-Columbia.

1. Purpose

An experiment with third and fourth graders was designed to answer the following questions:

(a) Which standard mathematics topics can be taught most effectively using the hand-held calculator?

(b) What implications does the hand-held calculator have for problem-solving situations?

(c) What new mathematical topics can be successfully introduced via the calculator?

2. Rationale

No explicit rationale is provided. This research is a sequel to a series of four mini-experiments conducted by the authors which explored ways to use electronic calculators with children aged 5-7 during the summer of 1974. Implicit in the article is the fact that hand-held calculators will have a major impact on the mathematics curriculum. Furthermore, investigations of third- and fourth-grade mathematical topics and their interaction with hand calculators need to be done if future curriculum are to reflect this tool.

3. Research Design and Procedures

A ten-week experimental study involving pre- and posttest measures on the Metropolitan Achievement Test (MAT) was done in the fall of 1974. During this period these students were given 32 instructional sessions (30-60 minutes in length) over a range of both standard and non-standard mathematical topics.

4. Findings

Only descriptive statistics were reported, with gains in grade level equivalents ranging from zero in problem solving for one student to one

year and nine months for the same student in computation.

5. Interpretations

Tentative answers to each of the three questions stated in the purpose are offered. Some interesting observations are reported, but they are not abstracted here because they rely completely upon the authors' subjective judgment rather than on any empirical evidence that was reported.

Critical Commentary

This investigation would have been ideal for a case study that allowed for careful observation and collection of selected data from the students. However, it was treated like the classical experimental study with pre and post measures. Given a sample of size three, this design prevents all but very gross interpretations of the data. In particular, it is hard to understand why the investigators relied completely on the problem-solving portion of a commercial standardized test when much more sensitive measures of problem solving exist in the mathematics education community. Only problem-solving performance on a paper-and-pencil test was examined, yet other aspects of problem solving, such as the process dimension, deserve attention.

Some of the instructional topics were listed. More details for their development would help this reader appreciate the nature and sequencing of the lessons. For example, one topic is described as "area". Without some elaboration, it is impossible to appreciate the capability of the calculator in developing this topic. The authors report that "throughout the ten week period, a great deal of time was spent reviewing and practicing the arithmetic operations with whole numbers and decimals." What does this mean? How much is a great deal of time? How were the calculators used in reviewing and practicing the operations? Without answers to such questions, it is impossible to get a feel for the instructional lessons which must be clearly understood if the findings are to be meaningful.

The authors cite several limitations of this study, including the small sample size (three students); the atypical teaching-learning environment; and the measurement instrument, MAT, which relies heavily on com-

putation and, by the authors' acknowledgement, was not a valid measure of mathematical performance. In light of the latter limitation, why was the MAT used at all? No rationale for its selection was provided. Were the instructional lessons in lieu of these students' regular mathematics program or in addition to it? How were the students selected? Why was no control group used?

Question 1 is an important research question that deserves careful attention. However, there are no results from this study that address the issue of "which topics can be taught most effectively." This question requires comparisons involving instructional options and none were involved here. The very best that these results provide is an existence that certain topics can be developed via a calculator. Unfortunately, the descriptions of the procedures are too sketchy to allow the reader to understand how the calculator was used to develop any of the topics. The answers offered for questions 2 and 3 are tenuous indeed, given the design and procedures for the study. Answers to such questions, if definitive answers do exist, will only be the result of carefully controlled longitudinal research.

Miller, Donald Peter. EFFECTIVENESS OF USING MINICALCULATORS AS AN INSTRUCTIONAL AID IN DEVELOPING THE CONCEPT AND SKILL OF LONG DIVISION AT THE FIFTH GRADE LEVEL. (The Florida State University, 1976.) Dissertation Abstracts International 37A: 6327; April 1977. [Order No. 77-8607]

Expanded abstract and analysis prepared especially for the Calculator Information Center by J. F. WEAVER, The University of Wisconsin-Madison.

1. Purpose

One intent was "to determine the effectiveness of using minicalculators as an aid in developing the concept and skill of long division" (involving two-digit divisors at the fifth-grade level). A second intent was "to determine how the use of minicalculators in this way will affect the prerequisite skills needed for the process."

2. Rationale

"Recent research related to the teaching and learning of long division has been concerned primarily with comparing the subtractive and the distributive approaches at the fourth grade level. At the same time, formal studies concerned with the difficulties encountered in the continued development of the process in grade five appear to have been non-existent. . . .

". . . If the use of minicalculators as an aid in developing long division can be demonstrated to be effective, then mathematics educators will have an additional tool for attacking this difficult process."

3. Research Design and Procedures

Campbell and Stanley's (1966) quasi-experimental nonequivalent control group design was extended to involve four groups of students formed by a partitioning of two intact fifth-grade classes:

HE (high experimental; N = 12)	O_1	X_1	O_2	O_3
HC (high control; N = 13)	O_1	X_2	O_2	O_3
LE (low experimental; N = 12)	O_1	X_3	O_2	O_4
LC (low control; N = 10)	O_1	X_4	O_2	O_4

O_1 and O_2 were identical: a 28-item test, constructed and used originally by Brownell (1951, 1953), consisting of seven multiplication exercises, seven subtraction exercises, and 14 division exercises involving one-digit divisors. Scores on O_1 were used to partition students in each of the two intact classes into two groups: high (raw scores greater than 14) and low (raw scores less than 15); and a flip of a coin decided which class would provide the experimental (calculators used) groups, with students from the other class providing the control (no calculators used) groups.

Each treatment consisted of twelve 50-minute periods of instruction based upon materials developed by the investigator to be consistent with a subtractive approach to the division algorithm, although from all indications this was not the approach used previously by students in grade 4 for their work with one-digit divisors. The "high" and "low" treatments were distinguished on the basis of "the degree of maturity to which the division algorithm was developed," with the two-digit divisors for the low groups being restricted principally to those that were multiples of 10.

Instruction pertaining to X_3 and X_4 was provided by the regular classroom teachers (each with more than 10 years of teaching experience). Instruction pertaining to X_1 and X_2 was provided by an undergraduate elementary education major who had a special interest in mathematics. Three training session for these teachers were conducted by the investigator, with additional meetings scheduled on the fifth and ninth days of the instructional period.

For groups HE and LE, one instructional period pertaining to the use of a calculator (Rockwell 8R) for whole-number addition, multiplication, subtraction, and repeated subtraction was provided on the day following O_1, prior to beginning the instructional treatments.

A procedure was devised whereby two observers (undergraduate students) noted and recorded frequency of calculator use by students in the HE and LE groups.

All tests were administered by the investigator, with O_2 and O_3/O_4 being made on consecutive days immediately following the 12-day instructional period. O_3 and O_4 involved 18 division exercises, prepared by the investigator to reflect the instructional delimitations that distinguished the high and low treatment groups. Groups HE and LE did not use calculators

on either the O_2 or the O_3/O_4 tests.

Data were analyzed principally on the basis of separate ANCOVAs for HE vs. HC groups and LE vs. LC groups, using O_2 and O_3 or O_4 as criterion measures and O_1 along with the total mathematics scores on the McGraw-Hill Comprehensive Test of Basic Skills, Level 2, Form S, as covariates. ("All test items were graded on the basis of right or wrong.")

4. Findings

On O_2, no significant difference in performance was observed between groups HE and HC; however, a significant difference ($\alpha = .05$) was observed between groups LE and LC (favoring the former).

On O_3, no significant difference in performance was observed between groups HE and HC; however, on O_4 a significant difference ($\alpha = .05$) was observed between groups LE and LC (favoring the former).

LE students used calculators either to find or check answers about two out of every three times they were observed; HE students used calculators either to find or check answers about two out of every five times they were observed. In both LE and HE groups, use of calculators to find answers was observed more frequently in the first day(s) of the instructional period than during the latter days of that period.

5. Interpretations

". . . the supportive use of calculators was effective in helping the experimental students to focus their attention on the algorithm rather than on the calculations involved. It appears that the calculator was particularly helpful to the students in the low experimental group. Analysis of the test results for this group clearly indicated that these students had a better understanding of the process than did the low-group students who had worked through the same materials without the aid of calculators. This result, if substantiated by further research, implies that the use of calculators, along with materials designed for their use, may enable students to learn long division while they are simultaneously gaining mastery of the prerequisite skills."

Critical Commentary

There is no need to discuss obvious limitations that are associated

with an investigation in which four treatment groups are formed from two intact classes at the same grade level within the same school. I therefore turn to other things.

a. It is unfortunate that posttests were restricted to those administered immmediately following a relatively short (12-day) instructional period. Would findings have been the same if post measures were taken again after some lapse of time? Or if taken after a longer instructional period?

b. Since groups that were compared did not differ significantly with respect to the pre measures (O_1 and the Comprehensive Test of Basic SKills), why both to use ANCOVAs rather than ANOVAs? (As well might be expected, on the criterion measures the differences between raw and adjusted means were of trivial magnitude, to say the least.) The reason for using ANCOVAs was not explicated by the investigator.

c. I fail to see how the data give any valid information about development of the concept of "long division" and understanding of the process. O_3 and O_4 were measures of computational skill only. Low scores on such tests might be construed to imply a low level of comprehension; but high scores do not necessarily imply a high level of comprehension.

d. Although high reliabilities were reported for the O_3 and O_4 posttests (KR-20's of .95 and .92 respectively), I suggest that any reader who has a serious interest in this investigation should look carefully at the test items. For instance, in the case of the O_4 posttest for the LE and LC groups: Why are there no items with zero remainders (as there are for the O_3 posttest)? Why do only 12 of the 18 items exhibit the principal delimitation placed upon the instructional work for the low groups: divisors that are multiples of 10? (Divisors for the other six items are 7, 53, 27, 71, 67, and 64.) And in the case of the O_3 posttest, one of the divisors is 304. Why?

e. On the O_4 posttest (18 items) the mean number of "rights" for the LC group was 3.00 (3.04 adjusted). The instructional treatment was relatively ineffective, to say the least, as measured by this posttest. It may very well be that LE would not have been significantly "better" than LC on O_4 if a more suitable instructional treatment had been designed for the LC group, Is it possible that certain other instructional treat-

ments also were not as suitable as might be desired? Or do the measuring instruments leave something to be desired?

f. O_2 involved subtraction items (7), multiplication items (7), and division items with one-digit divisors (14). It is not unlikely that, akin to Brownell's (1953) findings, treatment effects might differ across the three types of items. Miller's use of a single score in connection with the O_2 posttest obscures any such differential effect that might have in fact been present. Similar concern could be expressed regarding use of a single O_1 score to effect the high/low partitioning.

g. Is it simply a "slip," or is it a misconception on the part of the investigator when Table 3 is titled "Variances of Testing Instruments?" Testing instruments do not have variances.

How effective are minicalculators as an aid in developing the concept and skill of long division involving two-digit divisors at the fifth-grade level? What effect has such use of minicalculators upon prerequisite skills needed for the long division process?

I would be reluctant to suggest even tentative answers to these questions on the basis of the reported investigation.

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Expanded abstract and analysis prepared especially for the Calculator Information Center by DONALD J. DESSART, The University of Tennessee-Knoxville.

1. Purpose

The purpose of this study was to compare the attitudes and achievements of students participating in student choice and non-choice learning environments.

2. Rationale

An unstructured learning environment in which students are permitted to make choices from sets of activities predesigned by the teacher is a current practice in many school systems in the United States. These are often referred to as "mathematical laboratories" or "open classrooms". These can be contrasted with the more traditional, structured learning situations in which the teacher maintains a strong role throughout the learning experience. A study of the effectiveness of these two approaches is, obviously, a most worthy area of study.

3. Research Design and Procedures

Twelve seventh-grade mathematics classes including a total of 207 students were used in the study. These students came from a single, suburban junior high school and were members of the "regular" class; i.e., students with either very high or very low achievements were excluded from the group. The students were either members of the student-choice classes in which they selected activities from seven different areas (assignment cards, calculators, models and tangrams, recreational mathematical materials, graphing, self-paced progress in a regular test, and programmed remedial or enrichment units), or they were members of a traditional class in which a systematic study of materials in a seventh-grade textbook was guided by the teacher. The students in these latter classes were provided lectures by the teacher, were assigned homework, were given chapter tests, etc.

Whereas students in the traditional classes continued the same mode of study during the entire year, students in the experimental classes were exposed to a twenty-day treatment in the student-choice mode either during the fall, winter, or spring of 1973-74. No student participated in more than one of the experimental treatments.

All students were pretested during the first week of June 1973 with the Dutton (attitude) Scale and Section One of the Mathematics Attitude Inventory (MAI). The former scale measures attitudes toward arithmetic computation, and the latter scale measures attitude toward mathematics in general. In addition, the students were tested by the Cooperative Mathematics Test: Arithmetic to measure achievement.

During the 1973-74 year, the attitudes of all students in the study were tested five times from the conclusion of grade 6 to the end of grade 7. Achievement for the entire group was measured at the end of grade 6 and also at the end of grade 7. Achievement of the treatment groups was measured at the conclusions of the fall, winter, or spring treatments, respectively. IQ data from the Kuhlmann-Anderson Intelligenece Test were also available.

The attitude measurements were analyzed by a five (the five attitude measurements) by two (high and low IQ levels) by two (student choice or traditional) repeated measurements analysis of variance. Achievement data were analyzed by a three by two by two repeated measurements analysis of variance. The pre and post experimental data for the entire group were analyzed by a series of correlated t-tests.

4. Findings

There were no significant differences in attitudes as measured by the Dutton Scale between any of the experimental and traditional groups. Furthermore, there were no significant differences in attitude measured by the MAI for the three sets of experimental and traditional groups tested at the conclusion of the fall, winter, and spring treatments. However, when composite groups for the fall, winter, and spring treatments were pooled, attitudes for the experimental group were significantly greater than the traditional group ($p < .05$).

A significant decline ($p < .05$) in attitudes toward mathematics was found for the composite experimental group, the composite traditional group, and the total sample of 207 students for period from the end of grade 6

to the end of grade 7. It appeared that the decline was less severe for the composite experimental group.

There was no significant difference in mathematics achievement of the composite experimental and composite traditional groups. There was a significant increase ($p < .05$) in achievement for both the composite experimental and traditional groups from the beginning to the end of the academic year.

5. Interpretations

The author concluded that the attempt to improve attitudes by providing a student-choice environment may have been partially successful because the attitudes of the composte experimental group did not decline as much as those of the composite traditional group. Achievements, on the other hand, of the two groups did not differ. The decline in attitudes for the entire sample of 207 students is a finding consistent with research that seems to reveal that student attitudes toward mathematics do decline as students progress through school.

Critical Commentary

This study appeared to be carefully executed and treated from a purely statistical point-of-view. The usual limitations inherent in much of education research (limited treatment intervals, lack of complete randomization, etc.) were present to some extent in this study.

The study suffered from some rather serious flaws. For example, the measurement of attitude change for an entire year is commendable, but to expect much attitude alternation becuase of a mere twenty-day period is far too optimistic! Furthermore, the measurement of arithmetic achievement in this study seemed almost unrelated to the experimental treatments which provided limited opportunities for computational activity (for example, tangrams). A design in which the experimental activities would have been taught in a traditional manner as well as the experimental way, using a home-made test of achievement over the experimental topics, probably would have provided data upon which additional, and perhaps more valid, conclusions could have been reached.

[Note that conclusions specific to the use of calculators could not be made.]

Nelson, Dennis William. EFFECTS OF USING HAND CALCULATORS ON THE ATTITUDES AND COMPUTATIONAL SKILLS OF CHILDREN IN GRADES FOUR THROUGH SEVEN. (Arizona State University, 1976.) Dissertation Abstracts International 37A: 3382-3383; December 1976. [Order No. 76-27,270]

Expanded abstract and analysis prepared especially for the Calculator Information Center by JAMES M. MOSER, The University of Wisconsin-Madison.

1. Purpose

The major purpose of the study was to evaluate the effect of using hand calculators on the improvement of basic computational skills and on the improvement of attitudes toward mathematics among fourth-, fifth-, sixth-, and seventh-grade students.

2. Rationale

The reduced price of calculators has led to their widespread use. Many are being used by elementary-age children outside of class. Commercial companies are not producing software commercial materials to be used with hand calculators in the classroom. Thus, educators are in need of more empirical research to help them solve the fundamental problem of deciding what to do with calculators, and when. The review of literature dealt mainly with studies using non-electronic calculators and their effects upon student achievement and attitudes. Then the few studies available at the time of writing (1976) dealing with electronic machines were cited as well as anumber of "opinion" articles. The case was made for more research.

3. Research Design and Procedures

The study involved summer-school students [year of study never explicitly stated, although presumed to be 1975] from a rural district school (113 students) and metropolitan district school (83 students) in Arizona. About 22 percent were migrant students. Sixteen intact classes, eight from each school, were randomly selected in grades 4 through 7 (fourth graders: 90 Ss; fifth graders: 41 Ss; sixth graders: 50 Ss; seventh graders: 15 Ss). Four groups consisting of four classes, two classrooms from each school, were assigned to the treatment groups.

Control group (49 Ss): Lessons taken from "regular" mathematics program used during previous school year. No calculators.

Experimental I (45 Ss): Used the Aardvark Calculator Math program, a set of commerical workbooks covering the basic operations with whole numbers. Problems are to be solved by calculator. Each child had his or her own machine to use.

Experimental II (47 Ss): Used a calculator-involved program, designed by the author and Professor Gary Bitter of Arizona State University, involving 23 objectives on basic computational skills. Using a diagnosis-remediation framework, students worked on problem worksheets, puzzles, games, problem solving, and experimentation with calculators. In addition, a large number of innovative ideas were suggested to the teacher. Each child had his or her own calculator.

Experimental III (55 Ss): Each student had access to a calculator for free use in a random way to check answers or to experiment. The regular program in use in schools was implemented as in the Control group.

All classes met for 50 minutes each class day with its own instructor for a period of four weeks. It was not reported whether the class met every day of the week.

Computational skill was measured in a pre- and posttest by the Shaw-Hiele Basic Computational Skills Test, Form A, Part 1, "Whole Numbers." The test consisted of 20 items, five each in addition, subtraction, multiplication, and division. Attitudes were measured in pre- and posttest by the SMSG-developed (1968) attitude survey, PX 010 Scale Incentive Code, "Arithmetic Fun vs. Dull." It is a four-item Likert scale with five choices.

Analysis of covariance was used on adjusted mean gain scores for each of the four groups on attitudes and computational skills. Pair-wise comparisons were made between each separate group on each of the two measures, resulting in 12 tests. Each F ratio was tested for significance at the .05 level.

4. Findings

Each of the 12 comparisons was stated as a null hypothesis. Results are summarized in Table 1.

Table 1

Summary of Hypotheses

Hypothesis Number and Description	Result[a]
No significant difference between computation scores of . . .	
1. Control group and commercial calculator program[b]	.01
2. Control group and diagnosis-remediation calculator curriculum.	.01
3. Control group and group using calculators randomly. . .	.01
4. Commercial calculator program and diagnosis-remediation calculator curriculum	NR
5. Commercial calculator program and group using calculators randomly.	NR
6. Diagnosis-remediation calculator curriculum and group using calculators randomly.	.01
No significant difference between attitudinal scores of . . .	
7. Control group and commercial calculator program	.01
8. Control group and diagnosis-remediation calculator curriculum.	.01
9. Control group and group using calculators randomly. . .	.01
10. Commercial calculator program and diagnosis-remediation calculator curriculum	NR
11. Commercial calculator program and group using calculators randomly.	.01
12. Diagnosis-remediation calculator program and group using calculators randomly.	.01

[a] Figures indicate level of rejection; NR = not rejected.

[b] Underlined treatment is one with greater gain.

5. Interpretations

Gains in basic computational skills and attitudes of students towards mathematics can be significantly improved when hand calculators are used. Planned use of hand calculators in the mathematics curriculum improves computational skill gains and attitudes of students towards mathematics. It was felt that calculators can be of beneficial use in the mathematics curriculum. Replications were suggested for longer time periods, with different student populations, and with different areas of mathematical content. Further research was suggested on questions of differential benefit for the basic operations, differences in absenteeism, and best beginning grade for beneficial introduction of calculators. It was also suggested that retention measures be taken in any replication.

Critical Commentary

The study as described by the author has some very serious reporting flaws. Aside from the mention of grade level and location, there is no satisfactory description of the subjects. Why were they in a summer school? Were they remedial students or were they there for enrichment? Was there a predominance of one sex? More seriously, one really doesn't know much about the treatments. In the Control group and Experimental III the only characterization is that it was the "regular" program. What is that? A four-week program cannot be the same as a year-long one. Since one assumes that groups included children from different grade levels, how was a seventh-grade "regular" program different from a fourth-grade one? Were the regular programs at the rural location in extreme southwestern Arizona the same as those of the urban Phoenix area location? The characterization of Experimental III as having a random use of calculators does not help very much. Did all students use the calculator? And how often? Only once or twice? Every day?

Evaluation of data analysis was also difficult to interpret since only the F tables were given; no pre- or posttest or adjusted means were presented. Further data analysis by grade levels and/or by mathematical operation would also have helped to determine plausability of alternative hypotheses as to why one group performed better than another. As an example, Experimental II (the author's own program) performed better than Experimental III on computation. But, Experimental II had no fourth graders

and predominantly fifth and sixth graders, while Experimental III had almost all fourth graders [44 out of 55]. The computation test contained a sizeable number of items in multiplication and division that a normal fourth grader would not have seen during the year and would not have much of a chance of learning or mastering in a four-week summer program. Carrying out the analysis critique a step further, one wonders why in the original analysis as reported the author did not first carry out a simple 1 x 4 ANCOVA which would have given more power.

In summary, the overall lack of sufficient information and further analysis makes acceptance of results and findings very tenuous at best.

Nichols, Warren Elmer. THE USE OF ELECTRONIC CALCULATORS IN A BASIC MATHEMATICS COURSE FOR COLLEGE STUDENTS. (North Texas State University, 1975.) Dissertation Abstracts International 36A: 7919; June 1976. [Order No. 76-12,629]

Expanded abstract and analysis prepared especially for the Calculator Information Center by MARILYN ZWENG, University of Iowa.

1. Purpose

The investigator sought to determine if access to calculators in a college basic mathematics course would improve student achievement and attitude.

2. Rationale

If the use of hand-held calculators is found to improve attitudes or increase achievement in low-level college courses, colleges would have an inexpensive, valuable aid for making education more effective and relevant.

3. Research Design and Procedures

Two of the four sections of Basic Mathematics taught during the Fall of 1974 at Northwest Oklahoma State University were randomly assigned to the calculator treatment. Two teachers taught the four sections. Each teacher taught one calculator section and one non-calculator section. Instruction in both treatment groups was the same. Calculators were not used in lectures or demonstrations. During each class period, approximately 25 minutes was provided for working exercises in class. In the experimental groups, a calculator was provided for each student during the directed study period. Use of the calculator was optional, but students were observed to use them frequently.

The text used in Basic Mathematics was Meserve and Sobel's Introduction to Mathematics. The chapters of the book which were taught during the research project were "An Introduction to Sets", "Systems of Numeration", "Mathematical Systems", "Sets of Numbers", "An Introduction to Algebra", "An Introduction to Probability", and "An Introduction to Statistics".

A 50-item examination, "Math 113 Credit by Examination", constructed

by the mathematics department of Northwest Oklahoma State University, was used as both the pretest and the posttest. The McCallon-Brown Semantic Differential for Mathematics Attitude was also administered at the beginning and the end of the course. In analyzing the data, ACT scores, appropriate pretests, and instructors were used as covariates.

4. Findings

For the principal findings the author reports that there were no differences between the calculator and non-calculator groups with respect to attitude towards mathematics or achievement. Other findings reported were:

(a) No differences in either attitude or achievement existed between male students using calculators and female students using calculators.

(b) Students in the calculator group who had high ACT scores achieved significantly better than calculator students who had low ACT scores (even though the achievement scores had been adjusted for the ACT score effect).

(c) The adjusted means on attitude measures were also higher for the calculator group with high ACT scores than for the low aptitude calculator group.

5. Interpretations

The investigator recommends that electronic calculators will be more beneficial in improving attitude toward mathematics and achievement in college mathematics for students with high aptitude.

Critical Commentary

The major results of this study are certainly not surprising in view of the course content and the achievement test. The author claims that the calculator could be useful in about 60 percent of the course, but an examination of the achievement test provided in the appendix suggests that the calculator would be useful on at most five of the 50 items. (Note: The achievement test items were numbered from 1 to 29, and the references to a 50-item test were very confusing. However, by counting all parts of the items, one obtains a total of 50.) Number theory seems to be the only

topic for which a calculator would reduce computational drudgery -- the intended purpose of the calculator in the course. This study appears to be a case of getting an uninteresting answer to an uninteresting question!

With respect to the author's interpretation of his results, there are no bases for making the recommendations noted in (5) above. In order to say that calculators are "good" for high-ability groups and "bad" for low-ability groups, the achievement and attitudes of high-ability calculator groups should have been compared with the comparable non-calculator group. A similar comparison should have been made for the two low-ability groups.

Finally, it should be pointed out that according to the data provided in the appendix, the highest score on the posttest was 34 (68 percent on a 50-item test); the mean score (calculated by the abstractor) was 17.1 (34.2 percent). One must question either the quality of the instruction or the quality of the examination when achievement on a test which also served as the final examination in the course is this low.

Prigge, Glenn and Langemo, Janice. EFFECTS OF MINI-CALCULATORS ON THE PRE- AND CO-REQUISITE MATHEMATICAL SKILLS OF INTERMEDIATE SCHOOL CHILDREN. Grand Forks: University of North Dakota, Summer 1978.

Expanded abstract and analysis prepared especially for the Calculator Information Center by ROBERT E. REYS, University of Missouri-Columbia.

1. Purpose

This research was designed to investigate the effects of mini-calculators on the attitudes and mathematical skills of third-, fourth-, fifth-, and sixth-grade children.

2. Rationale

Calculators are very important in the school curriculum and becoming more available every day. Research on the effectiveness of mini-calculators in elementary schools is needed so that such evidence can guide future curricular and instructional decisions.

3. Research Design and Procedures

The four-week experimental study was conducted during the summer of 1978 with 30 volunteers from an enrichment program for third, fourth, fifth, and sixth graders. The students were then randomly assigned to either an experimental group or a control group. Each student in each group received specially prepared materials commensurate with ability level. The material was designed to allow children to work independently. All children covered the same mathematical concepts. A set of materials designed by the experimenter for calculator use was provided for both the control and experimental group. The experimental group was instructed to use the calculator to do them, whereas the control group was not encouraged to use calculators even though they were made available at each child's desk. In an effort to maintain compatibility between groups, several steps were taken: the researcher and his assistants were responsible for the instruction of both groups; the instructional time was constant across treatments; and a guided discovery method was used throughout the experiment.

A pretest-posttest design was used to examine performance on multiplication without a calculator and division without a calculator. An

analysis of covariance was used with the pretest serving as the covariate. Attitudinal data were also collected, but no statistical analyses other than reporting descriptive information was provided. A third dimension of the design involved two forms of five criterion-referenced tests taken during the four weeks of experimentation. One form was taken without a calculator, the other with a calculator. With the exception of an attitude survey instrument from SMSG, all of the evaluation instruments were constructed by the researcher.

4. Findings

No significant differences (.05) were found between the treatment groups on either the multiplication or division scores. The attitudinal data showed a very positive attitude toward mathematics at the beginning of the study, with very little change at the conclusion of the treatments. Pupil's (with and without calculator) scores on the criterion tests showed that as the computation problems became more difficult, the student's accuracy increases when calculators are used.

5. Interpretations

Voluntary use of calculators versus required use of calculators in doing mathematics assignments had little effect on student achievement on multiplication or division problems. Furthermore, there was no noticeable change of attitude toward mathematics among these groups. On skills in which students have varying degrees of competence, the students have a higher performance level if they are allowed to use a calculator. This holds implications for instruction, particularly for children unsuccessful in developing normal algorithmic techniques.

Critical Commentary

The overall design of this research is satisfactory, but for a variety of reasons the study lacks the base for any generalizations or definitive conclusions. In addition to the limitations acknowledged by the researcher, the following limitations place severe restrictions on the usefulness of this research:

1. The sample size. A total of only 30 students divided into two groups of 15 each provide the entire data base.

2. The nature of the sample. Only students volunteering for this summer enrichment program participated. Unfortunately, no other descriptive information (such as previous experience with calculators, ability, and/or achievement scores) regarding characteristics of these students are provided.
3. The length of treatment. Twenty instructional session including pre- and posttesting is far too short for monitoring educationally relevant changes.
4. The artificial nature of the treatment that required students to use calculators. This practice is not only unrealistic, but of questionable educational value even in a short-term research study. A control group without any calculator experinece would seem much more practical.
5. Lack of observational data on optional calculator use. If calculator use is optional, some record of calculator use should be maintained and reported. For example, how often were calculators used? When were calculators used? What students used them? etc. Such observational data would be very valuable, but none were mentioned.
6. Nearly all the observational instruments were constructed by the researcher and no accompanying information related to validity and/or reliability were provided.
7. The mathematical skills examined were limited to multiplication and division. Unfortunately, no look at higher order skills including problem-solving processes were attempted.
8. The learning activities provided were very routine computation and mirror contemporary mathematics textbooks. This raises serious questions regarding the appropriateness of these activities for calculator use. Although the exact form of the future calculator-oriented curriculum is not known, every forecast of change claims it will be quite different than the current mathematics curriculum. Some modifications could have made these activities far more amenable to calculator usage.

Quinn, Donald Ray. THE EFFECT OF THE USAGE OF A PROGRAMMABLE CALCULATOR UPON ACHIEVEMENT AND ATTITUDE OF EIGHTH AND NINTH GRADE ALGEBRA STUDENTS. (Saint Louis University, 1975.) Dissertation Abstracts International 36A: 4234-4235; January 1975. [Order No. 76-874]

Expanded abstract and analsis prepared especially for the Calculator Information Center by JAMES M. MOSER, The University of Wisconsin-Madison.

1. Purpose

The primary purpose of this study was to examine the effects of the usage of a programmable calculator upon achievement and attitude of eighth- and ninth-grade algebra students after the completion of a one-year course in algebra.

2. Rationale

The virtual "mathematization of culture" in the past twenty years has been greatly accelerated and intensified by the evolution of electronic devices. In the field of education, one emerging use of these devices is computational and is a means of simulating concepts within the present curriculum. The NCTM and the NASSP have endorsed the use of calculators in classrooms. Programmable calculators have many of the features of a computer, but do not share its high cost; they have a language that is ideally suited for instructional purposes where algebra is an underlying base. A well-written review of literature surveyed relevant studies in the areas of calculators, CAI, and attitude-achievement.

3. Research Design and Procedures

The study was conducted during the 1974-75 school year in a suburban St.. Louis, Missouri school district. All eighth-grade honors students and a sample of ninth-grade students from two junior high schools in the district were the subjects. Students in one school (51 eighth and 54 ninth graders) were designated as experimental, and those from the other school (21 eighth and 58 ninth graders) as control. The one school was designated as experimental because it had a Monroe 1880, Classmate IV programmable calculator available in its mathematics laboratory. Intact classes were used and ninth-grade calsses used were randomly chosen. All students had the same basic algebra content which was guided by

Modern Algebra Structure and Method (1970), published by Houghton Mifflin. The treatment consisted of methodically incorporating the computational and programming capability of the programmable calculator into the normal instructional program. Special emphasis was placed on evaluation of univariate and multivariate expressions, solution of linear and quadratic equations, and the solution of two-by-two systems of equations. After showing proficiency in working paper-and-pencil problems on a particular topic, the class used "mark-sense" programming cards to prepare programs related to the topic being studied. Each student processed his or her own programs. Existing pupil data were used as covariates -- the Short Form Test of Academic Aptitude (SFTAA) given in fifth grade and the Comprehensive Test of Basic Skills, Level 3, Form Q (CTBS) given in sixth grade. The criterion measure for algebra achievement was the Cooperative Mathematics Test: Algebra I, Form A (KR-20 reliabilities for eighth and ninth grades, .86 and .85 respectively). Mathematics attitude was measured in a pre- and posttest by the Mathematics Attitude Inventory (MAI) developed at the University of Minnesota. The MAI is a 48-item inventory (six scales with eight items per scale. The six scales are (1) Perception of the Mathematics Teacher, (2) Self-concept in Mathematics, (3) Value of Mathematics in Society), (4) Anxiety toward Mathematics, (5) Enjoyment of Mathematics, and (6) Motivation in Mathematics. The MAI is a four-response Likert scale. In the spring, the MAI posttest was given on the day prior to the administration of the algebra achievement test.

Separate analyses were made for eighth and ninth grades. For each grade, 19 null hypotheses were tested, each at the .05 level of significance. One hypothesis dealt with comparing final achievement between experimental and control; the other 18 dealt with attitude. For each of the six attitude scales, three hypotheses were examined -- change during the period of the study for the experimental, change during the period of the study for the control, and a comparison of experimental and control at the end of the study. Comparisons were examined using analysis of covariance. Changes were examined using a t-test, one-tailed for experimental group changes and two-tailed for control group changes.

4. Findings

There were no significant differences in algebra achievement between

groups at either grade level. Of the 18 attitudinal contrasts made for eighth graders, none resulted in a significant difference. For the ninth graders, 5 of the 18 contrasts resulted in significant differences. On the Anxiety toward Mathematics scale, the experimental group made a significant change for the better and the experimental group exhibited a higher score at the end than the control group. On the Value of Mathematics in Society scale the control group made a significant change for the worse. On the Self-concept in Mathematics scale, the control group had a significant loss over time and the experimental group exhibited a higher score at the end than the control group.

5. Interpretations

On the basis of the findings, the use of a programmable calculator as an aid in teaching algebra at the eight and ninth grades is not justified in terms of achievement. No claim of superior attitude can be made for eighth graders, although the results are somewhat mixed at the ninth grade. Anecdotal evidence supplied by teachers suggest that attitudinal evidence may be suspect because of poor timing of the administration of the test during the last (and warm, humid) month of the school year. Further research was suggested in other areas and levels of mathematics instruction, with a larger sample, with contrasts of programmable, non-programmable, and no calculators, into higher levels of cognitive behavior and other attitudinal dimensions.

Critical Commentary

There are several points of concern. In the thesis report, there is a severe lack of description of the experimental treatment. The amount of actual time spent on programming and interacting with the calculator should be documented, at least in terms of percentages of actual engaged time. Next, I would question the selection of the attitudinal measure. Six separate scales seemed to contribute very little except for data-analysis overkill. Finally, when the null hypotheses for the control group and the experimental group attitudinal changes over time are worded exactly the same, I question the propriety of using different statistical tests of significance for those hypotheses. Given that there was only one cal-

culator reported as existing in the experimental school in which five classes were involved, I wonder whether this was really a calculator study at all, or rather one dealing with programming.

Rudnick, Jesse A. and Krulik, Stephen. THE MINICALCULATOR: FRIEND OR FOE? Arithmetic Teacher 23: 654-656; December 1976.

Expanded abstract and analysis prepared especially for the Calculator Information Center by JAMES J. HIRSTEIN, University of Illinois.

1. Purpose

The stated purpose was "to measure the effect of the availability and use of a minicalculator on the students' total mathematics achievement and their ability to perform paper-and-pencil basic skills." A second purpose was to assess partent attitudes toward children's use of calculators in schools.

2. Rationale

Most calculator opinions are based on small-scale research. Some large-scale studies of the effects of calculator use need to be done.

3. Research Design and Procedures

The experiment was conducted using 600 seventh-grade students in two schools in West Chester, Pennsylvania. Half of the students were randomly selected at the beginning of the school year, given a calculator and a three-day instruction program on its use, then put "on their own" to use it all year. The other half of the students served as a control.

Attitude and overall mathematics achievement measures (not described) were given as pretests. Alternate forms were given in January and posttests were administered in June. One achievement posttest allowed the use of calculators, another did not.

A parent questionnaire was distributed during the summer prior to the experiment to assess parent attitudes regarding calculator use in schools.

4. Findings

The results of the parent questionnaire with 60 percent response rate are given in the report. Most questions got mixed reactions, with no clear majority favoring one response on questions involving prediction of overall performance or permission for calculator use. A clear majority

feared calculator dependence and a clear majority felt the school should provide instruction in calculator use.

Achievement data analyses were not complete, but a preliminary look indicated no difference between the two groups. No report of attitude results is given.

5. Interpretations

Overall achievement, including the ability to perform paper-and-pencil algorithms, did not suffer from calculator availability and use.

Critical Cmmentary

The instruments and the critical results are extremely sketchy in this report. The effort to conduct research on a larger-than-usual scale is commendable. However, in the absence of the hard data needed to answer the questions addressed, one would have to say this report is premature.

Scandura, Alice M.; Lowerre, George F.; Veneski, Jacqueline; and Scandura, Joseph M. USING ELECTRONIC CALCUTLATORS WITH ELEMENTARY SCHOOL CHILDREN. Educational Technology 16: 14-18; August 1976.

Expanded abstract and analysis prepared especially for Investigations in Mathematics Education* by CHARLOTTE WHEATLEY and GRAYSON WHEATLEY, Purdue University. Permission given to the Calculator Information Center to use.

1. Purpose

The purpose of these studies was to study calculator-assisted learning of mathematics by elementary school pupils with attention to computation, problem solving, motivation, instructional methods, and applicability to certain topics. Some of the questions asked were:

(1) What is the effect of calculator availability on the motivation of young children?

(2) Can five-year-olds profit from the use of calculators?

(3) What topics can be taught more effectively with a calculator?

(4) What implications does the calculator hold for problem solving?

2. Rationale

Because the small electronic calculator is becoming inexpensive and available, the authors thought it important to explore its impact on children's learning of mathematics. These studies were not conducted to test hypotheses but to generate hypotheses and to explore the feasibility of calculator use with primary school pupils in learning mathematics

This article reports the results of a set of five feasibility studies. None of the studies employed experimental controls or comparative statistics. The conclusions are based on observational data and pupil reactions to calculator use.

3. Research Design and Procedures

In a series of five exploratory investigations, pupils of aged five to nine used calculators in learning mathematics. The number of class sessions varied from eight to thirty-two. In experiment one, two groups

* Investigations in Mathematics Education 10: 43-46; Fall 1977.

of six-year-olds studied arithmetic, one with a calculator and the other without, in 15 lessons of 20 minutes each. The children in the non-calculator group made extensive use of manipulative materials. A similar comparison of calculator impact was made with five-year-olds in 30 lessons. Seven-year-old children solved cost problems encountered in shopping (e.g., amount of change when several items are purchased). This unit was eight lessons long. In a fourth study, five-year-olds learned to use a calculator either by free exploration or exposition. In the discovery group, the pupils learned by trial-and-error pushing of keys, while the exposition group was explicitly taught the function of keys. In a feasibility study with five third- and fourth-grade children, a variety of topics that might effectively be taught with a calculator were introduced in 32 class meetings of 30-60 minutes each.

4. Findings

The authors report their observations of the differences in the calculator and non-calculator groups. No performance comparisons were made. Five- and six-year-old children were observed to be highly motivated to study mathematics (typical grade-level topics), while control group pupils were not motivated by the mathematics or the use of manipulatives. The high interest displayed by the calculator group was sustained over the entire period of use. The children using calculators were less distracted, displayed longer attention spans, and worked independently for long periods of time. Contrastingly, the non-calculator group did not display interest, were confused by the manipulatives, showed little imagination, and waited for teacher direction.

The five-year-old children preferred a desktop calculator with larger display and keys. A group of five-year-old children taught by expository methods to use a calculator could solve presented problems, while a group allowed to explore calculators could not. Seven-year-old children were more highly motivated and more successful in problem solving than children not using calculators. Eight- and nine-year-old children showed marked mathematics achievement gains over a 10-week period while using calculators; some had more than a year grade-level gain in computation, concepts, and applications. The calculator was reported as being highly successful in motivating and assisting these children in learning mathematics.

5. Interpretations

The authors conclude that the learning of mathematics is facilitated by the use of calculators. Specifically they suggest that:

(1) place value (whole numbers and decimals), negative numbers, decimals, and factoring can be taught more effectively with a calculator,

(2) problem-solving skills can be greatly enhanced through use of calculators,

(3) the standard mathematics curriculum can be expanded to include use of numbers of greater magnitude,

(4) estimating skills, negative numbers, and decimals can be introduced at a much earlier time,

(5) computational skill may be enhanced through calculator practice.

Critical Commentary

This article reports five studies which were designed to explore the effects of calculator use in learning mathematics. The results are purely observational with no attempt to determine achievement differences. There is a definite place for exploratory studies in mathematics education research. Properly designed teaching experiments can lead to the identification of hypotheses for further study. They may allow the experimenter to understand the thought patterns of children. Results of teaching experiments can also lead to the development of curriculum materials. However, this report contains insufficient information for the interpretation of the results stated. In the first study, no details are given on (1) the number of subjects, (2) the size of instructional groups (Was the instruction in small groups?), (3) method(s) of instruction, or (4) the number of calculators per group (Did each pupil have a calculator?). Yet the authors conclude, based on observation, that the calculator-assisted learning was vastly superior. Care must be exercised in interpreting and utilizing findings based solely on the impressions of the experimenters. Additional detail would have provided the reader with the necessary information to interpret the conclusions.

While the observational results favor the calculator groups, no comparative performance data were reported. It is possible that the non-calculator group, appearing less motivated, may have achieved more. No

assertation is being made that this was, in fact, the case in this study, but the possibility must be considered.

The low interest level reported for pupils using manipulatives is not in agreement with numerous studies which have established the motivational value of manipulative materials. One is led to suspect a teacher-bias effect against the non-calculator group.

The study with eight- and nine-year-old children had only five subjects. The authors chose to report achievement test results on only three of these five subjects. Why only these three? What were the scores for the other two? The practice of selecting data to report is highly questionable. The number of subjects in the other four studies is not reported.

The study comparing "discovery and exposition" teaching strategies was poorly conceived. To give five-year-old children calculators without any direction and expect them to "discover" calculator logic is unreasonable. While it may not be necessary to teach explicitly each key function, at least children need suggested activities to incorporate the calculator as a tool in their thinking. A better test of the discovery approach would be to teach children to use calculators and then let them explore.

It is quite clear that the authors were very impressed with the advantages of calculator use in learning mathematics. While the calculator may be a valuable new instructional aid, the total effect of calculator-assisted instruction must await more careful evaluation. We do not often find panaceas for the problems of education; it is doubtful that the calculator is one.

Scandura, Joseph M.; Lowerre, George F.; Scandura, Alice M.; and Veneski, Jacqueline. USING ELECTRONIC CALCULATORS WITH CHILDREN AGES 5-7: FOUR MINI-EXPERIMENTS. School Science and Mathematics 78: 545-552; November 1978.

Expanded abstract and analysis prepared especially for the Calculator Information Center by ROBERT E. REYS, University of Missouri-Columbia.

1. Purpose

An investigation to explore ways in which electronic calculators could be used with children aged 5 to 7 and to study some short-term effects of their use.

2. Rationale

The availability of low-cost calculators is certain to have a major impact on schools and the mathematics curriculum in particular. Investigations of contemporary K-2 mathematics topics that are available to calculator usage are needed if future curricula are to reflect this potentially powerful tool.

3. Research Design and Procedures

Four quasi mini-experiments conducted during the summer of 1975 are described.

Study I involved six-year-olds and compared computation performance with and without the calculator following a series of 15 lessons of about 20 minutes each.

Study II made comparisons similar to Study I but involved five-year-olds. Instruction was on readiness activities and involved 30 lessons. Hand-held calculators were used until roughly halfway through the study, when a larger desk-model calculator was also provided.

Study III involved seven-year-olds. It compared problem-solving performance in practical application situations with and without the calculator and consisted of eight lessons of 20-25 minutes each.

Study IV involved eight lessons with five-year-olds. It was designed to determine the relative effects of specific instructional lessons using a calculator (expository) as contrasted with an open-ended exploration using a calculator (discovery).

4. Findings

Descriptive results are reported exclusively and reflect general observations of the authors. Only some of their commentary follows:

Study I: The calculator group was highly enthusiastic, showed what seemed to be an increased concentration span, worked independently, and enjoyed making their own problems with large numbers. Monitoring what the children were doing with the calculators was often difficult, even with a small group of four children. The non-calculator group took longer to get on-task, got bogged down forming numerals, and were highly dependent on teacher direction.

Study II: Reported results compatible with Study I. Moreover, the children in the calculator group seemed to prefer the desk model of the calculator due to the ease in both reading and finding the keys.

Study III: Reported discernible effect on motivation with the non-calculator group showing little enthusiasm for these practical applications.

Study IV: Reported signs of frustration in discovery groups, with children making inefficient use of the calculator and wanting some specific direction.

5. Interpretations

Calculators provided a constant motivation, irrespective of the child's age, previous mathematical experience, or ability. Children using calculators showed longer attention spans, were more creative in forming new problems, used free time for calculator activities, and completed assigned tasks in less time and with greater accuracy. Individual differences are magnified by electronic calculators, which places an increased responsibility on the teacher to monitor the activities. In regard to the mathematics curriculum, it is suggested that increased emphasis be given to estimation, place value, and problem solving.

Critical Commentary

Under no circumstances would this study be considered a quality piece of research. Its flaws seem limitless but only a few will be identified. Its saving grace is its pragmatic nature and the hope that it would encourage more classroom teachers to engage in careful observation of children in a variety of learning situations.

Four different studies are reported, but no rationale for this organization and design was given. No overall or theoretical framework for this particular collection of studies is described or even suggested. No rationale for the particular model of calculator used in these studies is provided.

What about the subjects in the studies? There is no mention as to how these subjects were chosen. Although their ages (between 5 and 7 years) are reported, no background data regarding individual characteristics such as ability are provided. In fact, the number of children involved in each study was not reported! Furthermore, the short duration of the studies (a summer with no follow-up) places additional restrictions on any interpretations, generalizations, and/or implications offered.

What empirical evidence was provided to support the findings? No objective measures of any type were reported, although comparative statements such as "achieved greater mastery", "made more specific mathematical gains", or "a discernible effect on motivation" were made. Without some support information, the reader must rely totally on the judgments of the authors.

What about the reliability and/or validity of the observational data? How objective and/or subjective were the authors? (This issue becomes even more critical since this research was supported by a private calculator company.) What specific observational techniques were used? Actually, all of the reported results rely heavily on observational data. This style provides a freshness lacking in many research studies, but it also requires carefully established and clearly defined experimental procedures if the results are to be meaningful.

Some further questions raised but not answered in this report:

Study I: 1. Why did the calculator and non-calculator groups both use the calculator for the first two lessons?

2. Why weren't concrete materials including the calculator also used with the calculator group?

Study II: 1. What does it mean that "emphasis was placed on readiness activities"? Some 30 lessons were given but readiness activities were never operationally defined.

2. What specific mathematical gains were made? (Computation? Concepts? Applications?)

Study III: 1. What were the nature and emphasis of the problem-solving lessons? Was there an instructional sequence that alerted children to different problem-solving strategies, including one-, two-, and multi-step problems?

2. Was the same treatment used with both groups? For the non-calculator group it is reported that the teacher did the calculations (i.e., served as the calculator). In this abstractor's judgment, this setting is so artificial that it lacks appeal and would provide no motivation.

3. Were any results related to problem-solving performance available? That is, were there differences in the processes used, number of different solutions, persistence in seeking solutions, as well as the number of correct solutions?

Study IV: 1. Why is the discovery label used? The nature of these lessons is clearly guided discovery, the only question being the amount of guidance provided. Even the amount of guidance given varies among lessons.

2. Why compare discovery versus exposition presentations with five-year-olds? This suggests a clear dichotomy that is not supported by current instructional practices.

In this abstractor's judgment, the value of this paper lies in its pragmatic nature. The classroom implications provide helpful suggestions and insightful comments regarding calculator usage with children. Several appropriate curricular implications were offered, but conspicuous by its absence was any mention of decimals. This report includes many helpful observations but unfortunately lacks in specifics related to theoretical structure, sample, treatment, data collection, and analysis. It defied replication and perhaps that's the way it should be.

Schafer, Pauline; Bell, Max S.; and Crown, Warren D. CALCULATORS IN SOME FIFTH-GRADE CLASSROOMS: A PRELIMINARY LOOK. Elementary School Journal 76: 27-31; October 1975.

Expanded abstract and analysis prepared especially for Investigations in Mathmatics Education* by JOHN E. TARR and JACK D. WILKINSON, University of Northern Iowa. Permission given to the Calculator Information Center to use.

1. Purpose

The primary hypothesis investigated was that pupils who had briefly explored calculators would do better on an arithmetic achievement test than pupils who had not explored calculators.

2. Rationale

The study was intended to begin exploration in the use of electronic calculators in the classrooms, to make informal classroom observations, and to generate some hypotheses (especially on achievement testing). The writers report that thus far there are few research-based answers to questions related to classroom use of calculators.

3. Research Design and Procedures

The study compared arithmetic achievement scores of two groups of pupils -- an experimental group and a control group. The inquiry was conducted in April 1974, in five fifth-grade classrooms of the University of Chicago Laboratory School, where the pupils are predominantly from middle- and upper-middle-class families and generally score above the national norms on standardized tests. Three classes (69 pupils) served as the experimental group; two classes (46 pupils) served as the control group.

Pupils in the experimental group were given calculators to explore for fifty minutes on each of two days. They were given problems to do and were encouraged to ask questions about the calculators.

The Mathematics Computation Test (distributed by the Educational Testing Service) was used as both a pretest and a posttest. Each item

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* Investigations in Mathematics Education 9: 44-46; Spring 1976.

was categorized as either a calculator or a non-calculator example. Thus, an administration of the test yielded three scores: (1) the whole score; i.e., the number of examples correct on the entire test; (2) the calculator score; i.e., the number of examples correct that required either the use of some additional information or a two- or three-step computation; (3) the non-calculator score; i.e., the examples not scored for the calculator score.

Form A of the test was given in February 1974, and used as the pretest. Form B of the test was given as a posttest about a week after the experimental group had its two-day calculator experience in April 1974. The pretests showed no significant differences between the control and experimental groups on any of the three raw scores. The posttest data were summarized and a t-test used to examine the differences in the means.

4. Findings

The posttest results for calculator and non-calculator examples are given in the following table.

Type of Examples	Group	Number of Pupils	Mean Score	Standard Deviation	t
Calculator	Experimental	69	22.91	1.78	4.204*
	Control	46	20.96	3.20	
Non-calculator	Experimental	69	17.71	5.61	1.269+
	Control	46	18.98	1.27	

* Significant at the .001 level
\+ Not significant

There was no difference reported between the groups on the pretest whole score.

The partial scores for the groups show a highly significant difference in favor of the experimental group in the performance on calculator

examples. On non-calculator examples the performance of the experimental group was not statistically different from that of the control group.

5. Interpretations

Pupils using calculators answered more of the calculator examples than they would have without them. The use of calculators may help on examples where calculation is the main issue.

There may be some loss from trying to use calcuators when they are not appropriate. The performance of the experimental group was poorer than that of the control group. Perhaps the pupils in the experimental group depended too much on the calculators.

Pupils made few attempt to estimate answers, even to the proper order of magnitude. This skill is almost essential if calculators are to be used effectively.

Curiosity ran high and interest in learning additional mathematical content was keen. In the classes that were introduced to calculators, motivation and interest were boosted substantially and pupils generated many questions that could easily have been exploited to begin a series of explorations about mathematics.

Critical Commentary

There is little question as to the need for action and developmental research dealing with the role and use of the hand-held calculator in teaching mathematics. This article provides both direction for future researchers and questions for current practitioners.

The fact that pretest data were not reported created some question in the way the data dealing with non-calculator examples were interpreted.

The writers infer that this non-significant difference may be interpreted to mean that "perhaps the pupils in the experimental group depend too much on calculators." Later they state that, "there may be some loss from trying to use calculators when they are not appropriate." How reasonable is it to make these inferences when the treatment and control groups may have varied that much on the pretest?

The nature of the treatment was not clear. The writers state that the experimental group was given calculators to explore and that "children were given problems to do and were encouraged to ask questions about the

machines." Some additional information regarding instruction would have been helpful. Would the nature of the instruction, type of examples, and problems be the most important variable in any study of this sort?

The study suggests implications for further research. One slight variation of the study would be to consider four groups: (1) Calculator experience; pencil and paper on test; (2) Calculator experience; calculator used on test; (3) No calculator experience; pencil and paper on test; (4) No calculator experience; calculator used on test. This study considered groups (2) and (3); another study could consider all four. Other questions for further research include: If the use of calculators were more than simply a two-day exploratory experience, but rather a one-week, structured experience using materials written specifically for the calculator, would even greater differences in scores be found? If materials were used with calculators in which common difficulties were encountered and pupils were sensitized to these difficulties, would they then perform better on the non-calculator examples? Are the high-interest aspects of calculator-usage lasting effects or short-lived effects? Perhaps of greatest importance is the question, do pupils with calculators better learn mathematical concepts and skill?

Schnur, James O. and Lang, Jerry W. JUST PUSHING BUTTONS OR LEARNING? -- A CASE FOR MINICALCULATORS. Arithmetic Teacher 23: 559-562; November 1976.

Expanded abstract and anlysis prepared especially for the Calculator Information Center by DENNIS ROBERTS, The Pennsylvania State University.

1. Purpose

The purpose of the study was to seek answers to the following questions:

a. Would controlled use of calculators improve the mathematical computational ability of elementary school children and transfer to situations where calculators could not used?

b. Would there be different degrees of calculator effects depending on the sex of the children?

c. Would there be differential degrees of calculator effects depending on the ethnic/economic background of the children (migrant/non-migrant status)?

2. Rationale

No rationale or research predictions were offered concerning the expected outcomes. Several references were cited indicating that some authors had suggested reasons why calculators should have positive impacts, while other authors had spoken out against the use of calculators in the schools.

3. Research Design and Procedures

The research study took place in Franklin Elementary School in Muscatine, Iowa during the summer of 1975. The sample consisted of 60 students enrolled in a compensatory summer program. Twenty-five of the 60 students were classified as dependents of migrant parents. Males and females were first randomly assigned to four classrooms as were the migrant/non-migrant children. Following this, two of the four classrooms were randomly designated as experimental (calculator usage) and the other two were classified as the control (no calculator usage).

During the one-month program, instruction to all four classes was the same with the exception of the use or non-use of calculators. Classroom

exercises focused on the four basic arithmecic operations using whole numbers from both standardized curriculum material and teacher-constructed material. In the experimental classes, students shared the use of eight four-function calculators. One experimental class used all eight of the machines, followed by the second experimental class using all eight. The experimental teachers first taught students how to operate the calculators and then made sure (by logging time on a time sheet) each student used a calculator for a minimum of 50 minutes per week. Students were shown how to use the calculator for verifying answers to problems worked first by hand and how to solve actual problems (about one-third of the practice exercises). All students were pretested with Form A of the Individualized Computational Skills Program Computational Test 3-4 (published by Houghton Mifflin) and posttested with Form B of the same test. Students in the experimental groups were not allowed to use calculators on the posttest. Results were analyzed using a three-factor analysis of variance -- the factors being calculator usage, sex, and migrant status.

4. Findings

A table of means was not presented for descriptive purposes. The results of the analysis of variance showed a significant effect for calculator usage -- that is, those who used calculators during instruction performed better on the posttest even though they did not use the calculator on the test itself. Neither sex nor migrant status showed significant effects nor were any of the interactions significant.

5. Interpretations

No interpretation was offered as to why the experimental group performed better on the posttest. The closest thing to an interpretative statement was the comment that the results seem to indicate that calculators could be integrated into such a program in a positive way.

Critical Commentary

It is difficult to interpret the results for several reasons. First, the fact that there was no sex difference found leads one to be somewhat suspicious of the data. In general, males do better than females on

such tasks. Second, there was no discussion concerning how teachers were assigned to the classes, thus allowing the interpretive possibility that the experimental group teachers were more favorable (and perhaps provided extra assistance) towards calculator usage. Third, and by far the most important, no theoretical base was offered on which to place the results in context. In what sense should a calculator be beneficial to students' learning of computational skills that would allow them to perform computations better even when the calculator was not available? It would have been very helpful if the authors had presented an explanatory link between the findings and some rationale.

Shirey, John Reginald. THE EFFECTS OF COMPUTER-AUGMENTED INSTRUCTION ON STUDENTS' ACHIEVEMENT AND ATTITUDES. (University of Oregon, 1976.) Dissertation Abstracts International 37A: 3386-3387; December 1976. [Order No. 76-27680]

Expanded abstract and analysis prepared especially for the Calculator Information Center by RALPH A. LIGUORI, University of Texas at El Paso.

1. Purpose

The investigation was to determine whether students using computer-augmented instruction perform differently than their counterparts using a calculator during instruction on measures of performance and attitudes after a unit concerning interest on home mortgage.

2. Rationale

The reported study was a replication of earlier research on the effects of using a computer as part of an instructional unit with the unique aspects of a much shorter unit of study, an exploration of its impact upon inducing rules governing relationships between variables, and the use of calculators in the control group. The author cited studies which used the computer merely to provide drill and practice as well as studies in which students were involved with the computer in a more complex interaction. The literature indicates that the computer-trained groups did as well or better than traditionally trained groups in studies lasting at least a semester. No references concerning the use of the calculator in an instructional sequence were cited. The use of the calculator in a control group should more fairly demonstrate any advantage of the computer-assisted instruction over less expensive alternatives.

3. Research Design and Procedures

The study took place in the Winston Churchill High School of Eugene, Oregon, which has an open-campus policy. Students in grades 10-12 were randomly assigned to the computer (n = 22) and the calculator groups (N = 30). Students were given pretests on vocabulary, knowledge, and attitudes on the first day. Both groups were given identical instruction on home mortgages during the next six days, as well as

experience in running canned computer programs. On day eight the students were given the same tests of knowledge and attitudes as they were given on day one. During the next three days, students worked independently, with the computer group using a computer program to complete their exercises and the calculator group using calculators. The tests of knowledge and attitudes were readministered on the twelfth day and again two weeks later. A replication of this process was performed with nine students in each group.

Four scales were developed to measure the students' attitudes towards using the computer in business, in government, in science, and by oneself. A test was given to determine a student's ability to calculate the interest on a home mortgage. Another test measured each student's understanding of the relationship among the amount borrowed, interest rate, time of loan, and amount of monthly payment. Finally, a measure to determine each student's attitude toward the unit of instruction was developed.

The scores from the second administration of the various instruments were used as covariates in the analysis of variance of each of those tests, except for the attitude of oneself toward the computer, where an analysis of variance was used. A chi-square test was used to determine if there was a difference in the number of inquiry exercises attempted by each group. Finally, t-tests were used to test for differences in the attitudes toward the unit.

4. Findings

The measures of achievement yielded no significant differences between the groups in either the original study or the replication study. On the replication study the computer group scored significantly higher than the calculator group on the attitude toward oneself's use of the computer, but on all other attitudes toward the computer the two groups did not differ significantly. In the original study significantly more calculator students performed some experimentation beyond the minimum when compared to the computer group; a similar pattern, but non-significant, was found in the replication. No significant difference in attitude toward the unit was observed in either study.

5. Interpretations

It appears that in this experiment the computer did not cause more learning to occur than did the calculator because such a small part of the total unit was spent using the computer. The program used to teach students using the computer was relatively slow and probably accounts for the fact that more calculator students did additional work than did computer students. There was some contamination caused by the observation by some calculator group students of the computer group working on the computer. The length of time that students were actually using the computer was not sufficient to establish any differences between the groups.

Critical Commentary

The researcher went to great lengths to insure that the computer and calculator groups were equivalent and then introduced a manipulation which was most likely too brief to yield any differences. However, it is noteworthy that more students taught using the hand-held calculator attempted additional experimentation than did their computer-taught counterparts. Perhaps in a study of greater duration this would also lead to superiority of the calculator group on other measures of achievement. It would have been a more complete experiment if a traditionally taught section had been included as a group. This is not a strong study, but it does add support to the evidence of the viability of the calculator as a teaching aid.

Smith, Buddy Lee. A STUDY OF THE EFFECTIVENESS OF THE USE OF THE ELECTRONIC CALCULATORS IN TEACHING THE SIMPLEX METHOD TO BUSINESS AND ECONOMICS MAJORS. (North Texas State University, 1977.) Dissertation Abstracts International 38A: 3986; January 1978. [Order No. 77-29,574]

Expanded abstract and analysis prepared especially for the Calculator Information Center by EDWARD C. BEARDSLEE, Seattle Pacific University.

1. Purpose

The purpose of this study was to analyze the effect of using electronic calculators in teaching the simplex method for solving linear programming problems upon university students' attitudes and achievement in mathematics. Six hypotheses were tested using an experimental (calculator) group and a control group. Smith hypothesized that for the experimental group there would be no pre-post change in attitude, no posttest difference in attitude or achievement between males and females, and no change in posttest attitude for students with ACT mathematics scores of less than 21 compared to students with ACT scores of 21 or greater. Comparing the experimental and control groups, there would be no posttest difference in attitude or achievement.

2. Rationale

With the increased availability and decreased cost of electronic calculators, Smith and others suggest that calculators should be used throughout the mathematics curriculum and that research involving their use is essential. Since the simplex method involves tedious computation, Smith felt that a student using the calculator to perform the routine computation would be able to grasp a better understanding of the process and hence enjoy the topic more. Thus Smith conjectured that use of the calculator would improve a student's attitude toward mathematics and would contribute to an increase in a student's achievement. Smith's review of the literature revealed that few studies have been conducted utilizing electronic calculators in the classroom and those studies have dealt mainly with low-ability primary or secondary level mathematics students or college students who used the calculator for a limited time.

3. Research Design and Procedures

The study was conducted during the first summer session of 1975 at Texas A & I University, Kingsville, Texas. The subjects were 69 students enrolled in two sections of Mathematics for Business and Economics I (Math 116), which is a required course for all mathematics majors. Two sections of this course were offered. Since both sections were at the same time during the day, students were randomly assigned to the control and experimental groups using a computer program. There were 35 students in the control group and 34 in the experimental group. Two teachers were used to teach the two sections. Both teachers had five or more years of experience and had taught the course before. The selection of the instructor to teach the control group was made by a flip of a coin. The simplex method was taught for ten consecutive days. The text used was Foundations of Mathematics by Bush and Young, Chapter 10. The teaching presentations to both groups were similar. Each group met once a day, five times a week, with each class meeting 80 minutes in length. Forty minutes of each class were used for lecture and answering questions; the remaining time was used for students to work on given assignments and obtain individual help as needed. During each class, each member of the experimental group had a Texas Instruments TI-30 at his or her desk, while the students in the control group used no calculators during the class periods. Fifteen minutes of the first class period were used to familiarize students in the experimental group with the operation of the calculators.

The Revised Math Attitude Scale by Aiken and Dreger was administered during the first class period to both sections at the beginning of the study of the simplex method. Also administered was the achievement test (Simplex Test). This test was the simplex portion of the Math 116 Departmental Final constructed by the mathematics department of the university. The test is given with only minor revision each semester and consists of 12 multiple-choice items. Both tests were administered after the ten days of instruction. Each hypothesis was tested by the appropriate t-test at the 0.05 level of significance. The instrument for identifying aptitude was the American College Testing Program (ACT) test.

4. Findings

The t-test on the means from the attitude pre-posttest was statistically significant for the experimental group, while the achievement posttest attitude means were not significantly different for either the males versus females in the experimental group or for the experimental group versus the control group. Also, there was no statistically significant difference in attitude posttest mean scores for students in the experimental group who had scores less than 21 on the ACT test compared to those who scored greater than or equal to 21 on the ACT test. No statistically significant differences were found in achievement either on the achievement posttest means for the control versus experimental groups or for the males versus females in the experimental group.

5. Interpretations

From the results of the study, Smith drew the following conclusions:

(a) There is little difference in attitude toward mathematics for students who use calculators in the classroom and those who do not use them.

(b) There is little difference in attitude toward mathematics of females and males who use electronic calculators in the classroom.

(c) There is little difference in attitude toward mathematics for students with higher aptitude in mathematics than for students with lower aptitude in mathematics.

(d) There is little difference in achievement in mathematics for students who use calculators in the classroom and those who do not use them.

(e) There is little difference in achievement in mathematics of females and males who use electronic calculators in the classroom.

Based on the findings of the study, Smith made the following recommendations: (a) the study should take a greater length of time since the ten days were not long enough to show changes and many students had just begun to master the calculator; (b) the study should be carried out for other mathematics courses at the college level; and (c) controls should also be made on the teacher variable. In this study the calculator was used only to relieve the computation; it should also be used in other ways than just computation and checking computation.

Critical Commentary

In addition to those recommendations presented in the study, several other observations seem warranted. The experimental design appears to be faulty. Although pre-post tests in attitude and achievement were administered to all subjects, the pretest achievement results were not reported nor used in the study. A pre-post statistical procedure was not followed. Also, the researcher used multiple t-tests to compare means when an analysis of variance would appear to be more appropriate. The arbitrary choice of a score of 21 on the ACT to identify low aptitude and high aptitude also seems questionable. The short duration of the study, two weeks or 10 class days, could cause test-retest reliability difficulties since the same instruments used for the pretest were also used for the posttest. Parallel forms of the instruments (at least the achievement test) should be more reliable.

No mention was made whether calculator use outside of class was encouraged or discouraged, which could confound results. The experimental group was not permitted to use the calculators on the achievement posttest. Since the students had been required to use the machines while learning the concepts, being deprived of using them on the posttest could have affected results. If the calculator is to be used in instruction, it should also be used for testing unless this is one of the hypotheses being tested. To test this type of hypothesis may require that tests and curricular materials will need to be redesigned to make use of the calculator.

As was recommended by the author, additional studies should be conducted which involve the calculator in all phases of college mathematics. However, in doing so researchers should attempt to control as amany variables involving the calculator as possible. Several aspects of this study suggest that outcomes would not favor the calculator group. Future studies should attempt to reduce bias for or against the calculator.

Sutherlin, William Norman. THE POCKET CALCULATOR: ITS EFFECT ON THE ACQUISITION OF DECIMAL ESTIMATION SKILLS AT INTERMEDIATE GRADE LEVELS. (University of Oregon, 1976.) Dissertation Abstracts International 37A: 5663; March 1977. [Order No. 77-4762]

Expanded abstract and analysis prepared especially for the Calculator Information Center by RALPH A. LIGUORI, University of Texas at El Paso.

1. Purpose

The study investigated whether the use of the hand-held calculator by sixth-grade students in a unit on estimation would lead to superior scores on a posttest and/or a retention test when compared to students taught the estimation unit without access to calculators. A subsidiary question studied was whether using calculators produced a differential effect based upon the ability level of students.

2. Rationale

The increased emphasis upon the metric system has increased the need to be able to work with decimals. The calculator is suited to aid in the spread of the metric system because of its decimal characteristics and its increasing availability. In all endeavours involving measurement and machine calculation the ability to estimate is crucial. The literature review was well designed and included a discussion of studies which had investigated the use of the calculator as an instructional aid as well as references to the role of estimation and the sequencing of decimals and fractions in the intermediate grades.

3. Research Design and Procedures

Four geographically and demographically dispersed Oregon schools volunteered the use of some or all of their sixth-grade classes for the study. Each school contained an experimental and a control group. The experimental group (N = 84) used the calculators for all precise work and only used a pencil to record the calculator algorithm if needed, a mentally estimated answer, and the calculator-derived answer. The control group (N = 88) used traditional paper-and-pencil methods and recorded estimates as well. In order to combat a potential "Hawthorne effect" the control classes were promised the use of the calculator after

the experiment. The same teachers taught both experimental and control groups within each school, concurrently. In one school students were randomly assigned to each group but in the remaining schools intact classrooms were used; thus the unit of measurement was the classroom average. All subjects were statistically and subjectively assigned to one of four arbitrary quartile levels of achievement.

The experimental period was three weeks in length and not less than 12 lessons. The teachers were given suggestions and help by the author and they used on-hand instructional materials. A set of suggested supplemental teaching guides was provided. Two forms of an experimental instrument were designed by the author and used in a pilot study; they were found to have a Kuder-Richardson reliability of .84. Calculators and scratchwork were not permitted during any of the testing; answers were to be achieved by mental estimation.

The prestest was given at the beginning of week 1 and the posttest at the end of week 3. The long-term retention test was given near week 7 or 8. Only students present for all testing and most of the instructional period were included. Analysis of variance and covariance procedures were used on all data presented.

4. Findings

Three null-hypotheses were tested. No significant differences were found between the experimental and control group on the pretest, posttest, or retention test. There were no differential effects found in the quartile membership due to the experimental manipulation.

5. Interpretations

The results indicated that calculator use did not provide any advantage in the learning of estimation skills. Further, use of the calculator did not affect students differentially. The results indicated that time spent in study with calculators did not seem to detract from the mathematical growth of those involved. The fact that no difference between groups was exhibited might be due to sixth-graders' failure to value estimation and their unease with the imprecision of estimated answers. A longer study period, special methods for teaching estimation, different grade levels, or small-group or shared calculator settings are

possible subjects for additional research. A final question raised was how would the result of students given free choice among mental estimation, pencil and paper, and calculator in various situations relate to the observed results, and could that choice be modified by an appropriate intervention program?

Critical Commentary

The study was well designed and presented. It would appear that a larger population would be preferable for studying such a significant question. Further, it would take an impact of enormous proportions to affect the performance of sixth graders in a three-week period on a subject matter about which they have had a long history of exposure. Although sixth graders may have had little formal training in estimation, it is likely that all students have developed some estimation techniques by the sixth gade and further that their ability to estimate is certainly heavily dependent upon their abilities to perform the basic arithmetic operations. It would appear that covariance techniques using the students' prior arithmetic skills as the covariate would improve the study. In any case additional time to use the calculator in a variety of situations would provide a truer test of the calculator's effect upon the learning of sixth graders.

Vaughn, Larry Richard. A PROBLEM OF THE EFFECTS ON HAND-HELD CALCULATORS AND A SPECIALLY DESIGNED CURRICULUM ON ATTITUDE TOWARD MATHEMATICS, AND RETENTION OF MATHEMATICAL SKILLS. (University of Houston, 1976.) Dissertation Abstracts International 37A: 4938-4939; February 1977. [Order No. 77-1529]

Expanded abstract and analysis prepared especially for the Calculator Information Center by PEGGY A. HOUSE, University of Minnesota.

1. Purpose

The study compared low-achieving ninth graders using calculators and a specially designed curriculum with similar students in a regular Fundamentals of Mathematics (FOM) program for differences in attitude (specifically, enjoyment of mathematics and anxiety toward mathematics) and for differences in achievement and retention of skill in a unit on decimals and percents.

2. Rationale

Knowledge of results (reinforcement) is believed to increase the probability of learning, and feedback during the learning process is seen as particularly important because it allows for corrective action. The calculator can serve an important function in providing feedback, and it can facilitate other areas of investigation and exploration of mathematical topics. The literature surveyed conveyed a generalized enthusiasm for calculators in the classroom, but little data-based evidence of their effectiveness. Also, the investigator found no previous attempts to alter the curriculum to accommodate calculator usage.

3. Research Design and Procedures

The study involved eight FOM classes in three schools in two adjourning districts of metropolitan Houston. FOM students are defined by the Texas Education Agency to be at least two years below grade-level achievement. Intact classroom groups were used, but their eight teachers were randomly assigned to treatments: four experimental classes which used calculators and the special curriculum and four comparison classes which used the regular state-adopted text and no calculators. A total of 101 Ss began the study (55 experimental, 46 control). Complete data were available for

61 (33 experimental, 38 control).

The special curriculum was written by the investigator. It concluded a unit on the use of the calculator and instructional modules featuring behavioral objectives, pre- and posttests, enabling activities, and answer keys. Teachers could use the modules either in an individualized manner or in lieu of a textbook. No attempt was made to regulate or monitor teachers' classroom behavior in either group.

Pupils were given an attitude pretest using Aiken's Revised Math Attitude Scale two weeks before the experimental period. At the beginning of the experiment, Ss were pretested for achievement using a test designed by the investigator. Eight weeks of instruction followed although elapsed time was almost three months including the Christmas holidays. Two posttests were administered: the Aiken attitude scale followed by a parallel form of the investigator's achievement test. The retention test, given two weeks later, used the original pretest instrument. The investigator reports a Kuder-Richardson Formula 20 reliability index of .94 for the Aiken instrument. The validity of the achievement test was determined by a panel of experts, and its reliability was established through a pilot test in three other FOM classes. The KR-20 reliability was calculated to range from .778 to .816 and was judged to be acceptable.

A multiple regression analysis was performed to determine if enjoyment of mathematics, anxiety toward mathematics, achievement and/or retention could differentiate between the two groups when pretest differences were accounted for.

4. Findings

Students in the experimental and comparison groups exhibited a significant difference ($p < .05$) in achievement as measured by the investigator's test on decimals and percents. Experimental Ss had the higher mean score. Neither dimension of attitude proved to be a significant differentiating variable. There also were no significant differences in retention.

5. Interpretations

The investor recommends the addition of calculators with an accompanying curriculum to the FOM program. He further observed a need to

train teachers, but does not elaborate on the nature of such training or on the rationale underlying the recommendation. Decimals and percents may be topics particularly suited to calculator usage, and the study should be extended to the other topics in the FOM program. It also should be repeated with other grade and ability levels and with different socioeconomic groups. Attitudinal changes should be studied over a longer period of time. Efforts are needed to develop maaterials and curricula suited to calculator use.

Critical Commentary

The greatest strength of this study lies in its recognition of the need to adapt the curriculum to accommodate the use of calculators. However, the report leaves so many questions unanswered that it would be inappropriate to base decisions on the results.

First, the reader is given an inadequate description of the "special curriculum." One sample module which is included raises questions about the development of the concepts. In the sample, pupils use the calculator to investigate multiplication of decimals as repeated addition. This works well in the first part where decimals are multiplied by whole numbers (.7 x 5), but the multiplication of two decimals (.0348 x .76) is presented as a button-pushing algorithm. It is not clear how well concepts are developed in the modules. Neither is it reported what concepts were included or whether these were established to be equivalent to the text material in the control classes.

A second major unknown is the testing condition for the achievement and retention tests. No students used calculators in the pretests, but no explicit information is reported on calculator use for later tests. If neither or both groups used calculators on the tests, then one group was tested under conditions which did not match the treatment. If only experimental Ss used calculators, then the comparison Ss were being tested on different variables such as memory of multiplication facts and placement of decimals.

The investigator does not justify his use of individuals rather than classes as the experimental unit, and the number of pupils per class is not reported. There also is no indication of how teachers used the modules whether for individualized or group instruction, and no observa-

tions are reported of whether pupils and/or teachers used the calculators as intended. These unknowns make it difficult to interpret or to replicate the study.

Studies which take account of the interaction of the calculator with the curriculum should be encouraged. Perhaps a more fruitful approach would be to consider a 2 x 2 design in which calculator usage is crossed with the use of specially designed curricular materials.

Wajeeh, Abdullah. THE EFFECT OF A PROGRAM OF MEANINGFUL AND RELEVANT MATHEMATICS ON THE ACHIEVEMENT OF THE NINTH GRADE GENERAL MATHEMATICS STUDENT. (Wayne State University, 1976.) Dissertation Abstracts International 37A: 2801-2802; November 1976. [Order No. 76-26,189]

Expanded abstract and analysis prepared especially for the Calculator Information Center by PEGGY A. HOUSE, University of Minnesota.

1. Purpose

The purpose of the study was to design, implement, and evaluate a 15-week program of "meaningful and relevant mathematics" for ninth-grade general mathematics and to determine the effect of using calculators with those materials.

2. Rationale

"Meaningful and relevant mathematics" is used to describe applications of arithmetic which one is likely to encounter in home, store, bank, job, etc. (e.g., time cards, installment buying, paychecks, budget). It also was defined to include recreational mathematics such as games, puzzles, and magic squares. Such a program was hypothesized to promote pupil motivation and interest and to have significant results with respect to achievement, attitude, and attendance. The calculator was given a two-fold purpose: first, to provide immediate verification and reinforcement (after paper-and-pencil solutions), and second to be used directly in solving the recreational puzzles.

3. Research Design and Procedures

The study involved five teachers and 13 sections of ninth-grade general mathematics in one inner-city Detroit high school. Students were assigned to the classes by their counselors without regard for IQ, achievement, or attitude; classes were assigned to teachers before the semester began.

Five units of instruction were developed by the investigator. These covered consumer mathematics, sports mathematics, mathematics and the world of work, measurement skills, and recreational mathematics. Lessons from the first four units were integrated throughout the semester.

Lessons from the recreational mathematics unit were regularly presented every Friday. All units were evaluated for relevancy and meaningfulness by a panel of experts and then revised according to their suggestions prior to the experiment.

Six experimental classes used the investigator's units for one semester; seven control classes used the general mathematics text adopted by the Detroit Public Schools. Three of the five teachers (including the investigator) were each assigned three or more sections of general mathematics. Each teacher arbitrarily selected one class to study the experimental program using the calculator (E_1), one class to study the program without the calculator (E_2), and the remaining class(es) to study the text material without calculators (C_1). (E_1 classes had 10 calculators, one for each three pupils.) The other two teachers had one and two classes, respectively, which were designated C_2 and which also studied the assigned text without calculators. Complete data were available for 389 Ss, and class sizes ranged from 25 to 35. In order to obtain equal cell sizes, Ss were randomly eliminated as necessary to bring each class to 25.

The investigator used a 3 x 3 factorial design to compare the treatments (E_1, E_2, C_1) in the classes taught by the three experimental teachers for their effect on achievement and attitude. Three measures of achievement were derived from the California Achievement Test, Mathematics, Level 5, Form A (1970) ($r = .9$): total mathematics achievement, computation, and concepts and problems. Attitude was measured using Dutton's Attitude Test ($r = .94$). All Ss were pretested using the above scales during the first week of the semester and posttested using the same battery during the last week.

For each of the above measures a one-way ANOVA was performed on the pretest to determine if the four groups were homogeneous with respect to the given variable. If that ANOVA was non-significant (e.g., if the groups were not significantly different), then a 3 x 3 factorial ANOVA was performed on the posttest for the E_1, E_2, and C_1 groups. If, on the other hand, the groups were not homogeneous, then a 3 x 3 factorial analysis of covariance was used on the posttest with the pretest as covariate.

4. Findings

The four groups were homogeneous with respect to total achievement, computation, and attitude before the experiment. The ANOVA results on the posttests showed significant differences ($p < .05$) both for treatments and for teachers in all three cases. Interaction effects were significant only for computation. Orthogonal contrasts among treatments for experimental versus control groups were significant ($p < .05$) for all three criteria and consistently in favor of the experimental classes. E_1 classes performed significantly better ($p < .05$) than E_2 on computation, but the experimental groups could not be differentiated on the basis of total achievement or attitude.

The groups were not homogeneous with respect to the concepts and problems dimension, and this necessitated a 3 x 3 factorial analysis of covariance using the concepts and problems pretest as a covariate. Significant results ($p < .05$) were found among treatments but not for teachers or for interaction, and the orthogonal contrasts showed the experimental groups to be superior to the control.

A comparison of the total achievement between C_1 and C_2 using Student's t-test was non-significant implying that the experimental teachers were not biased by the study. No other comparisons involving C_2 were reported. No contrasts among teachers were reported for any of the significant main effects.

Attendance records kept by the teachers showed the experimental Ss were absent less than the control Ss. Responses to a questionnaire designed by the investigator to reflect pupil attitude were tablulated and reported without analysis or comment. Narrative comments by six Ss and two Ts were reprinted without interpretation.

5. Interpretations

Since the content of the course was assumed to be equivalent for experimental and control classes, the author attributed the achievement differences to the experimental unit's focus on meaningful and relevant arithmetic. Differences in attitude gain scores were hypothesized to be related to the relevance of the material, pupils' enjoyment of the mathematical games, and the informal classroom atmosphere during the recreational mathematics. Comparisons between E_1 and E_2 might have been

different if Ss had used the calculators in the problems rather than only to check answers.

Critical Commentary

The study yields more information about the effects of the curriculum approach than about the effectiveness of the calculator. In fact, the non-significant differences between E_1 and E_2 in all but computation suggest that the two treatments were quite similar. This may very well be due to restricting the calculator to checking answers. It also is compatible with the superiority of E_1 on computation since the calculator probably provided important reinforcement.

The data analysis seems incomplete, however. When treatment main effects were significant, orthogonal contrasts were examined, but when teacher main effects were significant no further analysis was reported. No interpretations were offered for significant teacher effects. Also, C_1 and C_2 were compared only for total mathematics achievement, but not on any other variables.

It is also difficult to account for the Ns in the study. The author reports on 13 classes of 25, yet tables report four treatment groups of 75 Ss (three classes of 25) each -- 12 classes. The explanation of this is obscure.

While experimental Ss had fewer absences, the experimenter does not establish that this difference is significant. Yet, in his discussion it is not always clear whether he is assuming a significance which may not exist or whether he is hinting at a causality among the treatment variables. This tendency to make suggestions which may not be warranted weakens the objectivity of the discussion.

Hopefully, too, future studies will use the calculators in more creative ways and will assure that each pupil has a calculator for individual use. The outcomes of the recreational mathematics units also deserve closer examination.

Yvon, Bernard R. and Downing, Davis A. ATTITUDES TOWARD CALCULATOR USAGE IN SCHOOLS: A SURVEY OF PARENTS AND TEACHERS. School Science and Mathematics 78: 410-416; May-June 1978.

Expanded abstract and analysis prepared especially for the Calculator Information Center by J. F. WEAVER, The University of Wisconsin-Madison.

1. Purpose

The intent was to survey within two different towns the current feelings of parents and elementary teachers toward calculator usage in schools.

2. Rationale

The investigation was considered to be a "logical first step" toward having teachers and parents become well informed on the "volatile issue" of hand-held calculators and their use in schools.

3. Research Design and Procedures

A 12-item questionnaire was developed to ascertain:

a. feelings toward computation as the major goal of elementary and junior high school mathematics instruction, and the importance of developing speed as contrasted with understanding;

b. opinions regarding calculator usage in schools; and

c. within-the-home and on-the-job use of calculators.

Two towns were chosen for the survey: (A), a university-suburb comunity of about 5,000 population, and (B), an industrial-suburb community of about 10,000.

All K-8 teachers in town A and all K-9 teachers in town B were asked to complete the questionnaire, with returns approximating 35 to 45 percent.

Parents of students from one classroom at each grade level in each town were asked to complete the questionnaire, with a 35 to 45 percent return achieved.

Because of its crucial nature in connection with this abstract, the 12-item questionnaire is reproduced on the next page, sans some of the instructions.

Circle the number of the response which most closely expresses your feelings.

		SD	D	NS	A	SA
1.	The most important goal of elementary and junior high arithmetic is the ability to figure correctly with whole numbers, fractions and decimals.	1	2	3	4	5
2.	Speed in arithmetic is not as important as understanding how and when to use different arithmetic operations.	1	2	3	4	5
3.	Calculators should be a part of the math program in grades 3 through 6.	1	2	3	4	5
4.	Calculators should be a part of the math program in grades 7 and 8.	1	2	3	4	5
5.	Calculators should be a part of the math program in grades 9 through 12.	1	2	3	4	5
6.	Assuming they are available to all students, calculators should be used for homework assignments.	1	2	3	4	5
7.	Skills with calculators will be essential to children's future success.	1	2	3	4	5

How would you feel if calculators were used in the school in the following ways.

8.	Use of calculators is primarily for motivation, enrichment, and games.	1	2	3	4	5
9.	Use of calculators is taught along with pencil and paper solutions, with the teacher taking care to require that the student be competent both ways.	1	2	3	4	5
10.	Use of calculators with proper understanding can largely replace pencil and paper solutions.	1	2	3	4	5

		YES	NO
11.	Is there an electronic calculator in your home?	1	2
12.	Does a member of your family use an electronic calculator in his or her job?	1	2

SD: Strongly disagree
D: Disagree
NS: Not sure
A: Agree
SA: Strongly agree

4. Findings

Pooling across all replies from parents (91 in town A, 97 in town B) and teachers (19 in town A, 43 in town B), the following means were reported for items 1 through 10:

1 - 4.3	6 - 2.7
2 - 4.4	7 - 2.9
3 - 2.1	8 - 3.2
4 - 2.7	9 - 3.9
5 - 3.7	10 - 2.8

with 35 percent "Yes" responses on item 11 and 56 percent "Yes" responses on item 12.

When responses pooled across towns for all parents were compared with responses pooled across towns for all teachers, signficant differences between means were observed on four items: 3, 4, 8, and 10.

For town A parents compared with town B parents, significant differences between means were observed on three items: 1, 7, and 8.

Significant differences between means were observed on two items -- 3 and 8 -- when pooled responses across towns were compared for K-6 teachers and 7-9 teachers.

Several other comparisons evidenced no significant differences between response means.

5. Interpretations

Questionnaire returns reflected a definite negative feeling about the use of calculators in grades 3-6, a moderately negative feeling about calculator use in grades 7-8, and a positive feeling about calculator use in grades 9-12; also, a moderately negative feeling about calculator use for homework, and a slightly negative feeling about calculators being important. The most marked degree of agreement with questionnaire statements, on the part of both parents and teachers, was observed for items 1 and 2.

The fact that the distribution of responses on most items (and more particularly 4, 6, 7, and 10) had a relatively large variability (standard deviation) "should temper any firm conclusions."

Critical Commentary

It is not sufficient to "temper any firm conclusions," as suggested. It would be better simply to disregard the investigation and its findings.

I agree with the authors when they "suggest strongly that the feelings of parents and teachers not be ignored in developing new programs which incorporate calculator usage," and also mention "a definite need of more studies to assess attitudes of calculators." (There have been more since the authors conducted their survey in 1975.) But when in that connection the authors indicate that "Replication of any part or all of our questionnaire is invited," I demur and urge that the invitation be declined.

Most of the questionnaire items are of such a nebulous, ambiguous, etc., nature that I would be unable to answer them and would feel unable to interpret any set of responses derived from such items. Exactly how were the items developed? And what is the reliability of the instrument in relation to the groups surveyed? The authors' report gives no answer to either of these questions, nor to a host of other related questions that might be asked.

The rate (35 to 45 percent) and reported distribution of questionnaire returns raise serious questions of how representative the data were of the populations sampled -- to say nothing of generalizability to other populations. The parents' data are further suspect in light of the following vague and questionable sampling procedure: "Each town was asked to choose one classroom at each grade level for distribution of the parent questionnaires. . . . Questionnaires were sent home and returned via the students."

Finally, the authors indicate that "many subgroups were compared by means of a t-test." In fact, 48 such seemingly independent tests are reported, which raises serious doubt as to the validity of the statistical procedures for the data to which they were applied.

All in all, I find nothing about the reported investigation that contributes any useful information regarding any question that pertains to the use of hand-held calculators in connection with school mathematics instruction.

Zepp, Raymond Andrew. REASONING PATTERNS AND COMPUTATION ON PROPORTIONS PROBLEMS, AND THEIR INTERACTION WITH THE USE OF POCKET CALCULATORS IN NINTH GRADE AND COLLEGE. (The Ohio State University, 1975.) Dissertation Abstracts International 36A: 5181; February 1976. [Order No. 76-3605]

Expanded abstract and analysis prepared especially for the Calculator Information Center by JOE DAN AUSTIN, Rice University.

1. Purpose

"This study was conducted to identify groups of students who respond to proportions problems in various ways, and to determine the effectiveness of pocket calculators in solving problems involving proportions among those groups of students which exemplify certain developmental stages." (p. 1)

2. Rationale

Research by Piaget and Inhelder with young children has indicated that proportional thinking is not mastered until the formal operation state of development. This seems true even though the concepts of ratio and analogies are often observed in children at the concrete operaion stage. With older children some research, e.g., by Abramowitz and Karplus, suggests that ". . . there may be many people who never attain the formal stage of proportional thinking." (p. 4) The ability of a student to do a proportion problem depends on the problem as well as the proportion. Some proportions, e.g., 1:n for n small, seem easier than others, e.g., 3:5. There is also evidence that improper computation algorithms may prevent students from being able to solve proportion problems. "The basis hypothesis of the research reported in this dissertation is that poor computational skills in multiplication and division force students away from proportional thinking." (p. 6) If computational deficiencies are reasons for student problems with proportion problems, the calculator may prove to be very useful to students doing these types of problems.

3. Research Design and Procedures

Initially an eight-item pretest on proportional reasoning was constructed. The eight items were in four pairs. Each 'easy' ratio problem

was matched with a similar problem but with a 'hard' ratio. Using test scores and solution strategies, students could be classified into five levels of proportional reasoning ability. Three levels -- high, middle, and low -- were used in this study.

The pretest was given to 170 ninth-grade mathematics tudents and 198 college freshman education majors. This identified 85 ninth-grade and 38 college students in the high, middle, or low levels of proportional reasoning ability. These students were randomly divided into two groups. One group (experimental) would be permitted to use calculators, and the other group (control) would not.

The researcher prepared programmed materials consisting of three problems using linear interpolation to estimate square roots. This required about 25 to 30 minutes to complete. For the calculator group a calculator practice sheet with eight practice computations was prepared. This required about 10 to 15 minutes to complete. The posttest was four problems similar to the problems in the programmed materials.

The control group completed the programmed materials and then the untimed posttest. This group did not use calculators. The calculator group completed the practice sheet, the programmed materials, and then the untimed posttest. This group used a Texas Instruments Exactra 19, a calculator with four arithmetic operations, on all activities including the posttest. (To check pretest reliability, the ninth-grade computer group retook the pretest before doing the practice sheet. Using a linear scale for the five levels of proportional reasoning ability, a correlation of .8879 was obtained for the test and retest scores.)

The posttest scores were analyzed by a two-way analysis of variance. Separate analyses were made for the ninth-grade and college students. The two factors were treatment (two levels) and proportional reasoning ability level (three levels). The author also compared error patterns on the pretest data but used no statistical tests.

4. Findings

From the error patterns on the pretest, the researcher concluded that ". . . the response patterns of college and ninth grade students were roughly equivalent in each ability group." (p. 48) The researcher also felt that each of the proportional reasoning ability levels showed